OUTLINE OF SCIENCE

PART I

THE
WORLD'S ESSENTIAL KNOWLEDGE
VOLUME II

OUTLINE OF SCIENCE

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PART I
MAN AND HIS ENVIRONMENT

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PART I

I

THE UNIVERSE IN WHICH WE LIVE

Man Discovers the Solar System

ASTRONOMY is our oldest science. With little to do during the long dark evenings, it is not surprizing that thoughtful men should early have turned their attention to the study of the heavens. Particularly should this be expected when it is realized that the people of that early age were much more dependent upon the weather than are we to-day. All the bounties of nature proceeded from the heavens. The result was that altogether too much credit was given to the skies; they were even credited with control of all our destinies. Thus astrology grew up along with astronomy, and has only recently been shaken off.

The Chaldeans made a systematic study of astronomy as early as 4000 B. C., as evidenced by old records. They even predicted eclipses. The records show that the Chinese were able to

determine equinoxes and solstices as early as 1100 B. C. They had calculated the obliquity of the ecliptic and its diminution. The Greek philosophers from 600 B. C. to 300 B. C. taught that the stars shone from their own light, whereas the moon shone from reflected light. They even suggested that the earth was spherical and revolved around the sun. Hipparchus (150 B. C.) made a catalog of over a thousand stars, and divided them into six classes according to their brightness. With the decay of Greece, true astronomy slumbered until after the Renaissance. The new astronomy was born with Copernicus in 1500 A. D., and was carried forward by the observations of Tycho Brahe and the imagination and brilliance of Kepler, who gave us an exact statement of the motion of the planets and afforded a predicting power to astronomers which could not previously have been dreamed of.

Their work fell into the hands of able successors. Galileo invented the telescope, introduced the pendulum for the exact measurement of time, and recognized the true nature of motion and force. His experiments on falling bodies at the tower of Pisa constituted a greater step forward than had been taken for centuries previous, or, one might add, than has been taken since. Newton, about 1700, climaxed all that had gone before in the pronouncement of his universal law of gravitation. He pointed out, as it

were, what it was that made the wheels go around. This law reduced the motions of the heavenly bodies from an unfathomable mystery to a problem capable of exact calculation. The great mathematicians, Lagrange and Laplace, working on Newton's theory, demonstrated the mechanical stability of the solar system. This was a great confirmation of Newton's work. A greater came, however, in the work of Adams and La Verrier in the nineteenth century. Investigating the irregularities in the orbit of Uranus, they concluded that these could not be entirely due, as supposed, to Jupiter and Saturn. They were thus led to assert the existence of a hitherto undiscovered planet. They computed its exact orbit and its position in that orbit at the time. When telescopes examined the heavens for evidence of such a planet, it was found—an uncharted star of the eighth magnitude, not previously observed. It was the planet Neptune. A great triumph for the Newtonian theory!

Of late the astronomers have shifted their gaze from the solar system, the problems of which have been so thoroughly solved by such great minds as those mentioned above, and are investigating the nebulæ and the stars. We are now attempting to solve the problems of the universe. We want to know how stars and solar systems have their birth. We want to know the extent and the shape of the universe. Our modern

astronomers are doing admirable work. Our daily press is constantly announcing new achievements. The new vistas that are opened up to human thought are astounding. Astronomy today is influencing our lives as much as it did in the pre-Christian era.

Putting Stars in "Test Tubes"

The materials of which the sun and stars are made are the same as those found upon the earth. If we consider the sun, which in fact is our nearest star, we can say that as many as fifty-eight of the ninety-two known elements have been definitely identified in the sun's composition. Hence we may expect to find that the other stars are similarly composed, and while not so large a number have been found for these more distant heavenly bodies, they are doubtless there. It is quite unlikely that we shall ever be able to find all the known elements in the stars. Some, as is the case on our earth, may be present in quantities too small ever to make it a possible task.

In identifying these distant elements the method of spectroscopy is used. We recognize them by the light which they emit. Newton first placed a glass prism in front of a beam of sunlight and split it up into its component parts. This led to the extensive work of Fraunhofer, and later of Rowland, who definitely tabulated

the exact position in the sun's spectrum of an enormous number of distinct colors. These colors are referred to technically as lines. The extended Rowland table contains no less than 21,835 of these, of which 12,835 have been definitely identified as exactly like those which come from known earth-substances. The metals present in the sun in their order of abundance are magnesium, iron, silicon, sodium, potassium, and calcium, all of which are abundant on the earth. Those substances forming the greatest number of spectral lines are iron, titanium, chromium, cobalt, nickel, and vanadium. Among the most recently identified elements are atomic carbon, nitrogen, oxygen, and sulfur. Astronomers and physicists are still at work on this problem and doubtless many more elements will be identified in the next few years. The stars are not composed of materials foreign to us.

Stars vary in their distance from us from about twenty-five million million miles to a maximum of observable distance of five hundred million million miles. Their weight varies from as little as a millionth that of water per unit volume to a matter of several tons per cubic inch. Their diameters run from a few thousand miles across to several hundred times that of our sun, and their brightness varies from that of a flickering match to that of our most powerful electric arcs.

How can the stars vary to such an extent in density if their materials are those of the earth? We know of no material that even remotely approaches a value to be indicated in tons or even pounds per cubic inch. The explanation is based upon an interesting theory of the stars.

The only factor which stays within comparatively narrow limits for all stars is total mass. Here there is a variation of only a few hundred to one. Let us take this as our clew, for it has considerable significance. Temperature measurements of the stars, by means of sensitive electrical thermometers, show that they vary in temperature from 4000 degrees Fahrenheit to as much as 45,000 degrees. At such temperatures as exist at their centers it is obvious that all materials would become gaseous in nature. Ordinary hydrogen gas, at the temperature which exists in the interior of our stars, must travel at speeds easily approaching that of light. At these terrific speeds the atoms would be quickly broken up into their component parts, protons and electrons. These would be constantly bumping and recombining. We know that upon recombination the atom would emit radiation. Under star conditions these would be in the form of very short x-rays. As these started out from the center they would break up new atoms, and these, upon recombination, would again form radiation. This would be of slightly longer wave-

length then the first radiation, according to our theory based upon earth observations. Thus, as we go further toward the outside of the star, the radiations get longer and longer. It is the longest of those produced by the star which we are able to observe. The short waves are absorbed in the interior. We receive only the heat and light waves.

Will the Universe Completely Disappear?

If such a process is going on, we should expect that the stars would rapidly cool off. But observation has shown that they do not cool off with the rapidity which should be expected. This we now believe to be due to the possibility that the material of the star is itself being changed into radiant energy. This is not intended in the sense that coal is changed to radiant energy. Here the products of combustion could all be assembled and their combined weight would equal the original weight of the fuel. When matter is converted to energy in a star, the matter has been annihilated.

Suppose we attempt to make a star in space by combining positive and negative particles, those building-bricks of which all matter is composed. One positive and one negative will make a hydrogen atom. But we cannot have a star of hydrogen alone. We must build up some of the heavier atoms. The next above hydrogen is

helium. This has four negative and four positive particles in its make-up. Hydrogen has an atomic weight of 1.008. Helium has an atomic weight of 4. Yet helium has exactly four times the number of particles contained in hydrogen. If we put four hydrogen atoms together it should make a helium, but it will not weigh four times a hydrogen atom. If a pound of hydrogen were made into helium we would have 0.992 pound of helium and the remaining 0.008 pound of matter would have disappeared as radiation. This 0.008 pound of energy would be the equivalent of 430 billion horse-power. Thus, as we build up elements, the mass is partly dissipated as energy. Einstein has given an equation of direct equivalence of mass and energy. Because of this interchangeability, the sun will radiate for fifteen thousand billion years longer than it would if it were merely a cooling body. At the end of its life it will have completely disappeared. It will not be a cold body floating in space.

The basis for this radiation theory is supported by the small variation in total mass of stars, as already mentioned. Light exerts a small tho definite and measurable pressure. A body placed near one of these very hot stars would attempt to fall, due to the gravitational attraction, and would be repelled by the light pressure. It would take up a position of balance between these two and remain suspended in space. If a

star becomes too massive, the amount of radiation at its center will be so great that the outer material will be repelled from it. It might even break up with explosive violence. If the star is small, it will quickly cool. Thus the narrow limits between which the total mass falls gives a clue to the nature of mass and radiation. The splitting up of the star Nova Pictoris early in 1928 was ascribed by some astronomers as an explosion due to radiation pressure. There was, of course, much difference of opinion on this.

The fact that mass is continually changing to radiation would result in a complete annihilation of the universe if it were not elsewhere changing back to matter again. Experiments on cosmic rays indicate that this latter is occurring. Thus, if we do not ultimately have this universe, it appears that we shall have another fully as good, where the evolution of man may still go on. Now that definite boundaries have been set to our universe, we may still speculate as to what is beyond these when our present universe and its changes have been fully charted.

Astride a Light Ray to the End of Space

If we look at the summer sky on a clear evening, it has every appearance of a great dome studded with points of light of various brightnesses. We cannot, with the eye, determine anything of their distances. Do the brighter ones

appear so merely because they are nearer, or are they actually brighter? We can, by the usual methods of triangulation, determine the distance of some of the nearer ones. The method is a familiar one to all surveyors. But when we attempt to measure the distance of the farther ones, this method fails. The angles involved become too small for measurement. It is at this point that we must fall back on the brightness of the star itself for a measure of its distance from us.

A star may appear bright either because it is near us or because of its intrinsic brightness. A bright star is a hot star. As temperature increases, brightness increases. A piece of iron, when heated, becomes at first dull, then cherry red, gradually becoming whiter, until at its hottest we say it is white-hot. The same is true of a star. By measuring its degree of whiteness, so to speak, spectroscopically, we can thus tell whether it is truly a hot, and therefore a bright star, or whether it appears so because it is near us. This method has been developed into one which gives us very exact knowledge of star distances beyond that point where the method of triangulation is no longer of any value. By the use of these two methods we are able to map the universe.

A survey of the sky by the naked eye will perhaps reveal in the neighborhood of six thou-

sand stars. We see only the nearer and brighter ones. By the aid of a telescope we can increase this number to millions, for we can easily distinguish stars less than one-millionth as bright as the brightest of those seen with the naked eye. Our best telescopes, when used with photographic apparatus, bring this down to the ability to distinguish stars of one-hundred-millionth the brightness of those visible to the eye. With such instruments the universe has been largely charted. Let us see what we find.

Borrowing a method of description used by Professor Walter S. Adams, of Mount Wilson Observatory, let us follow the path taken by a light ray which begins its journey at our sun and travels outward with the usual light velocity of 186,000 miles per second. Such a light beam will pass our earth in about eight minutes. It will travel a lonesome path after leaving our solar system until it reaches Alpha Centauri, a dwarf star about as bright as the sun. This will be at the end of four years of travel. As it goes on, the ray will frequently meet with such stars as the one just named. They are scattered throughout space in every direction, but are too small and faint to be traced far with our telescopes. They are the local stops of our light ray. The first express stop would be the great white star, Sirius. The time-table shows that this would be nine light-years distant from our sun.

Calling only the express stops from here on, we find Vega, twenty-five years; Arcturus, forty years; the cluster of the Hyades, 130 years; the bright stars of the Pleiades and the belt of Orion, 500 to 600 light-years. From here on we are in unsettled country. The frequency of encounter with stars becomes less and less. At the end of 20,000 light-years we reach the first globular star cluster if we are traveling in the direction of the Milky Way, or if at right-angles to this, we are then reaching the boundaries of our star system. At the end of 100,000 light-years the light ray will find itself at the boundary of our own galaxy, or star group.

If it is our desire to proceed beyond this point, we shall next encounter certain star-clouds that are thought by some to have been broken off from our system of stars. Some of these that have been studied are from 100,000 to 700,000 light-years away. At 860,000 light-years we encounter Messier 33, and at 900,000 light-years the Andromeda Nebula, which appear to be nothing short of galaxies. Such galaxies have been studied as far out as 50,000,000 light-years, the distance of Coma Berenices, which has been studied extensively by Dr. E. P. Hubble. If you are exhausted by the journey through space at this rapid rate you will be pleased to know that you have now reached the boundary of our universe as far as it has been studied.

But is this the actual boundary, or are there, beyond this, other galaxies too distant for our present instruments to detect? Present theory would indicate that this is indeed the limit. Our universe appears to be curved, and, altho bounded, is infinite. It may be likened to a sphere. It has sharp boundaries, yet one traveling on it would never reach an end.

This view is supported by the fact that the most distant stars are apparently leaving us at a rate of several thousand miles a second. Either they are actually doing this, or the light is reaching us—according to theory—after it has passed around the universe. The latter seems the more plausible theory.

Beyond the limits of our universe we are never to see, provided it is thus bounded and curved. It will, accordingly, never be our privilege to know whether or not we are living in a universe or in a group of universes. This will be left to stir our imaginations long after we have discovered whether or not there is life on Mars.

Einstein Says the Universe is Curved

Suppose a stone is dropped from a moving train. To the man on the train observing it the stone appears to fall in a straight line. To a man standing on the ground the stone unquestionably travels a parabolic path to the earth. Both observers are right. The stone travels in a

straight line relative to the man on the train and a parabolic path relative to the man on the ground. All motion is relative. By a suitable system of coordinates all motions in the system of the stationary observer, no matter how complicated, could be changed over into the system of coordinates of the moving observer. In this way one could describe his observations to the other. These equations would be called the transformation equations. There is no fixed system of coordinates in terms of which all motion can be described. An observer off the earth would see occurrences on the earth in a wholly different way from the observer on the earth. Even the order of events might be reversed to the two observers.

These two observers are not even able to agree on time. Suppose they both stop and adjust their clocks so that the pendulums are swinging together. Now the moving observer sets off away from his friend with the speed of light. At once both decide that the other's clock has slowed down. The time between ticks will now be what it was before, plus the length of time required for the light to travel the distance which has been traveled by the clock since the last tick. If the moving observer turns around and approaches the stationary one, then the other's clock appears to each to be going faster than his own. He naturally believes his own to be correct,

altho the lack of agreement does not in reality exist. Neither clock has changed in the least. They only appear to have changed because of the relative motion.

The impossibility of our knowing anything of our surroundings absolutely can be illustrated in numerous ways. Let us take a familiar example due to the mathematician, Poincaré. Let us consider the plight of a group of individuals who can be assumed to live on a flat circular world whose temperature falls off as we go from the center toward the outer edge. Let us assume that all objects, including the residents of this world, contract in size with decreasing temperature in the same manner. Now, as one of these individuals moves outward he and all his surroundings decrease in size; his steps get shorter and shorter; he will never reach the edge. To him, his world appears infinite. To some one observing from the outside, it is finite; but an inhabitant may never learn of the boundaries. If he attempts to measure his universe, his measuring rods shorten as he goes out, much as ours shorten when we attempt to measure ether-drag. Examples can also be given in which an infinite world appears finite to its inhabitants.

Another factor which enters into relativity considerations is that of geometry. We are accustomed to the statements in Euclidean geometry that a straight line is the shortest distance

between two points, that the three angles of a triangle equal 180 degrees. These are true for the geometry of a plane. If a straight line and a triangle were drawn on a sheet of paper they could be wrapped around a cylinder or around a cone without distortion. The so-called axioms of plane geometry would still be true. But try to wrap the drawing around a sphere! This can only be done if we have used some material capable of being stretched. In this case we can fit the sphere closely, but the line and the triangle will have been distorted. If we now try to apply our laws of Euclidean geometry we shall arrive at peculiar results. We must accordingly revise our geometry. We must invent a spherical geometry. We might extend our systems of geometry to cover all sorts of cases. We might invent one that would apply to an egg-shaped object or even to a dumb-bell-shaped object. Such geometries become very complicated, but they are necessary to explain some of the results to which the theory of relativity leads us.

Plane geometry was invented by the Egyptians because of the necessity of annually resurveying the fertile land of the Nile Valley due to the seasonal floods. Plane geometry was all that they needed, for altho the earth was round, their measurements were on too small a scale to permit the detection of its sphericity by the surveying methods used. Had they measured over a suffi-

cient distance, however, they would have discovered errors in their work. These they might have attributed wholly to accidental errors characteristic of their methods, or they might have interpreted them as due to the earth's sphericity. They probably did not measure over distances, however, which led them into this difficulty. In much the same way we have never thought of the universe as curved. Exact measurements of which our modern astronomical instruments are capable have recently shown that stars near the edge of our universe appear to be traveling away from us with velocities of several thousand miles a second. It is necessary, because of this, that we either believe that we are the center of a great explosion or that space itself is curved. The latter seems to be the more reasonable assumption. We have for the first time made those measurements on the universe which the Egyptians might have made on the earth.

The theory of relativity leads us also to the conclusion that light itself has mass. If this is so, a beam of light passing near a very heavy object should fall toward it. This has been tested over and over again with beams of light from stars which pass close to the sun on their way to the earth. Because of the brilliance of the sun, this can be done only during an eclipse, when the light of the sun is obscured and the stars in its direction shine out clearly for a short time.

All measurements of this effect so far taken tend to confirm the theory, altho, because of the difficulty of making the measurements (there are many factors which enter to confuse the observer), it is still felt by many that additional data must be obtained before the theory can be accepted as a certainty.

The Long Arm of Astronomy Reaches Further

The era recently past has been marked, in astronomy, by the building and planning of instruments of much greater light-gathering capacity than have hitherto been used. Of these the sixty-inch reflector for the Harvard Observatory, Southern Branch, and the seventy-inch reflector built by the Bureau of Standards for Ohio Wesleyan University, are among the more notable. The two-hundred-inch quartz reflector to be built for Mount Wilson will, of course, eclipse both of these giants and start a new chapter in the history of astronomy.

The necessity for such instruments, if astronomy is to advance, is obvious. At the present time astronomers are working at the utmost limits of the accuracy of their instruments. Only a few of the nearer nebulæ are at present subject to study, and the more distant ones show no detail at all. They appear merely as star-like images. For spectroscopic study they require exposure-times of as much as one hun-

dred hours. The difficulty of making such long exposures is obvious; not every night is suitable for the observations.

What the 200-inch reflector will do for astronomy cannot be briefly described in more suitable words than those of Professor Walter S. Adams, of Mount Wilson Observatory, where the instrument is to be erected. Professor Adams writes as follows:

"The design of this huge instrument is being studied from the outset with a view to providing the greatest possible light-gathering power and efficiency to aid in the discovery and investigation of nebulæ and faint stars, the analysis of their light by the spectroscope, and the extension of the limits of space beyond those which can be attained with existing telescopes. The provisional design, to which much thought has been given during recent months, provides for a comparatively short focal length, about 3.3 times the aperture of the large mirror, to give great concentration of light, a fused quartz mirror to insure the quality of the images under varying conditions of temperature, and auxiliary mirrors to increase the effective focal length for such investigations as require higher magnifying power. Such a telescope would have a length of approximately sixty feet, a tube more than twenty feet in diameter, and a total weight of over 450 tons. The mirror itself, about three feet

in thickness, would weigh nearly thirty tons. The problems connected with the design and construction of this great instrument are such as to require the collective judgment of the most experienced engineers and instrument designers of the world. Similarly in the plans for its operation and the selection of the most fundamental problems for investigation, a very liberal attitude is being maintained by the trustees of the project to the end that its great possibilities may be utilized by astronomers in every field of research to which it can make notable contributions.

"On the basis of the performance of existing telescopes it is reasonable to conclude that the 200-inch reflector will multiply by a factor of perhaps eight the million or so nebulæ which we now know to exist. By about the same factor it will increase the number which can be studied in detail by the aid of variable stars and other recognized standards for measuring great distances. Stars of about one-tenth the light of the faintest stars we can at present see upon our photographic plates should appear on negatives taken with this instrument, and star-counts made from such records will amplify and improve greatly our knowledge of the structure and extent of our stellar system. What new methods for the study of the universes of stars may be developed through the immense light-gathering

power of the 200-inch telescope we cannot foresee, but from its use even with existing methods we can feel assured of discoveries of the highest value, ranging from the faint dwarf stars nearest to us to nebulæ whose distances approach comparison with the radius of our world of space and time."

II

CELESTIAL PHENOMENA

Celestial Vagabonds

THE comet is often considered as the most awe-inspiring spectacle presented to man's gaze. Certainly, of the astronomical phenomena that we are privileged to observe, it takes rank with the total eclipse. Many of us still remember the last visit of the magnificent Halley's comet. Its long brilliant tail sweeping across the sky was an impressive sight. Small wonder that the ancients fell on their knees before their gods and prayed to be delivered from the impending calamity which the comet's appearance was thought to foretell.

Nowadays we can view a comet with somewhat greater calm, and speculate upon its cause and place of birth. Do these comets come to us from interstellar space? Are they mere casual visitors to our solar system, which appear century after century with the regularity of cosmic mailmen? This is the view frequently held. There is much to support the belief that they are, however, a part of our own solar system. They belong to us.

Against this suggestion is the obvious fact that they could not have been associated with the solar system from its beginning. No comet

could have survived for 10,000,000,000 years, the estimated age of the solar system. If they are members of the solar system they must have been adopted since its beginning. They must have been adopted not more than 1,000,000 years ago to be in the stage of development in which we find them to-day. By mathematical reasoning, F. Nolke has arrived at the figures 50,000 to 100,000 years as their probable age.

But there are other bits of evidence which help us to place the age and source of these celestial visitors. There is an absence of meteors in the earth strata below 1,000,000 years. There is a close kinship between meteors and comets; they are both stray members of interstellar space. Each may be responsible for the building up of the other. They differ chiefly in size. The absence of meteors in the early geologic formations has been given by some as a reason for belief in the theory that comets were originated by being thrown off from the earth's crust. It is equally a support of the capture theory.

The earth is moving at a rate of twenty kilometers per second. In 15,000 years it travels as far as light travels in a single year. It is moving in a direction away from the constellation Orion. A million years ago it must have been in the neighborhood of Orion, where it is suspected that there are large quantities of meteoric dust. It seems quite probable that it was here that

the earth acquired its comets. It has been suggested that the interposition of meteoric dust between the sun and earth accounts also for our glacial age.

All our comets are headed toward the same fate. They are becoming mere meteors. Their tails are becoming less and less bright. Eventually they shall have completed their life span. There is insufficient meteoric material to form new comets in the present position of the earth. No new comets are appearing. It has also been suggested that our asteroids, small comets of the solar system, are in fact dead comets.

It has been suggested by some, notably Sir William Herschel, that the comets might gather material in the form of meteors when far from the sun, thus adding to their mass. Evidence shows, however, that this is not likely to be true. They are becoming less and less impressive. They apparently are not the sky-brooms they were once thought to be. The fact that they are all of the same material indicates a similar origin for all, and likewise offers evidence against the acquisition of new material from the heavens.

Our Celestial Coal-Pile

It requires only that one be well away from city lights on almost any night of the year to see what are called falling or shooting stars. Especially after midnight one should be able to see,

on a clear night, as many as six or eight of these in an hour. These so-called falling stars are, in fact, meteors. They vary in size from small dust specks up to several tons. It is estimated that the earth encounters thousands of millions of such meteors each day, and that the sun encounters as many as a trillion per second.

Meteors are composed for the most part of such elements as silicon, oxygen, iron, and magnesium. Comet tails which contain many small meteors show evidence of containing carbon, hydrogen, and nitrogen, as well as cyanogen gas. Owing to the extremely high temperatures of the hot stars it is quite impossible that they should contain such substances as iron, magnesium, and cyanogen. Yet there is sufficient evidence in the absorption spectrum of the outer layers to assure us that these materials are present in very small quantities. The same is true of the sun. This suggests that interstellar space is infested with them, and that they are falling into the distant stars. It is the only way to account for the presence of these meteoric materials, which cannot long exist at hot-star temperatures, in these stars. Thus, altho we can actually observe meteors only when they are rendered white-hot by friction with the earth's outer atmosphere, we can be quite certain that they are colliding with the stars and the sun just as they are with the earth.

It might be argued that these materials are in the outer atmosphere of the sun and stars in an atomic and molecular state. If they were thus present as gases it is impossible to imagine them falling into the stars. They would be repelled by the pressure of the stars' light. As solid meteors, however, the situation is very different; they should fall into the stars with enormous velocities. It is estimated that meteors should fall into the sun with the stupendous speed of 400 miles a second. For the larger stars, velocities as great as 1,000 miles a second would be reached.

This constant bombardment of the sun and stars by meteors may constitute a celestial coal-pile that will prolong the life of the universe for many millions of years. This comforting thought is given to us by Dr. Harlow Shapley. According to the modern theory, already explained, the universe is gradually running down because of the transmutation of matter into energy. Computation shows that the sun is losing no less than 4,200,000 tons of its mass per second. This loss of mass will prolong the life of the solar system for many years beyond that which it would have if it were merely a cooling body. Now, with the sun collecting meteors at the rate of a trillion per second, we find that we have part of this loss made up. It is even possible, if the sun in its progress through space

should be fortunate enough to encounter a region in which the number of meteors was especially large, that it would gain in size. In other words, the coal bin of our solar system would be replenished for another few billions of years. That the sun might pass through such a region is quite conceivable. There is evidence to show that the system actually was in just such a region, in the neighborhood of Orion, about a million years ago.

Probably, by means of meteors and by the rebuilding of atoms from radiation, as evidenced from a study of cosmic rays, the running down of the universe may be delayed for an almost endless time.

The Moon an Earth Child

According to generally accepted theory, the moon was at one time a part of our earth, and, owing to some major disturbance, was disrupted from it. Having been thrown off, it has continued to revolve around the earth, held by the centripetal force. That this force will some day bring it back to the earth has been suggested, with good reason, by Sir Oliver Lodge. It may appear contradictory that once having been thrown off it should ever return. We must remember that conditions have greatly changed since that time, however. When the moon was born there is evidence to show that the earth

revolved at the rate of once in five hours, instead of twenty-four, as now. The moon, revolving around the earth and held by the centripetal force, is like a great ball being revolved at the end of an elastic cord. At high speed it will stretch the cord, but as its energy is gradually used up it will come closer and closer to the hand, and eventually fall into it. The moon's energy is being slowly dissipated. This dissipation is taking place in our daily tides, for example. Thus, as the moon's energy disappears, it will slowly approach and eventually reach the earth. Rather an unwelcome visitor!

If the moon is a child of the earth, certainly it does not resemble its parent. This is, in part, due to the difference in size. Because of this the gravitational attraction on the moon is only about one-sixth that on the earth. Even the most anemic person, if placed upon the moon, could perform marvelous feats, other conditions than gravity being the same. He could carry a load that would weigh half a ton here. He could jump six times as high as his earth record.

But all this glory will never come to such an individual. The moon has practically no atmosphere as compared with ours. He would find practically nothing to breathe. This is because the gravitational attraction is too small to hold an atmosphere. Here, in turn, enter other difficulties. The atmosphere acts as a great blanket

to protect us from extremes of heat and cold. When the sun was shining on the moon-dweller he would find the heat great enough to boil water in the open. When the sun was not shining he would experience a cold such as is impossible of conception on the earth. And since the moon revolves but once in twenty-eight days, he would have sunshine for fourteen days and darkness for an equal period.

Whether or not there is water on the moon is a question. Some have held that the moon is encased in a great ice shell; others claim to have detected snow in some of the craters. If water is present, it is doubtless frozen.

The cause of the moon's familiar craters is still unknown. One theory is that they are due to bombardment by meteors. This seems most unlikely, however, for the earth is also subject to such bombardment and we find but one crater, in Arizona, which resembles those on the moon. This one, if on the moon, would be too small for us to see. Those on the moon are as much as five hundred miles across, and are about ten miles deep. It seems more likely that they have been caused by some eruption remotely resembling one of our volcanic disturbances. The variation in temperature between the upper sunny portions of the crater's edge and the lower shaded portions is enormous. The material of the moon,

judging from temperature changes observed, appears to be much like that of our volcanic ash.

In ancient times the belief existed that the moon had a profound effect upon mankind. Insane people were thought to have been affected by the moon. They were called lunatics. Of late our artificial lights have made us less dependent upon the moon, and we have largely dismissed it from our thoughts. We are now coming to believe, however, that it has more effect upon us than we have recently supposed. It will be more important to us in the future. Doubtless the tides will eventually be harnessed for power purposes. Plant growth, once thought to be affected by the moon, has in fact been found to be so to some extent. This is because the light from the moon is largely polarized. It has a tendency to vibrate all in one direction instead of haphazardly. A close study has shown the moon to have an effect upon animal life as well, particularly upon reproduction. We may yet find some of the old traditions of our forefathers, lately scouted, put upon a firm scientific basis.

Can a Light Ray Bend?

There is nothing mystical about an eclipse. The moon merely gets between the earth and the sun, and obscures the sun's light. The effect is, however, thrilling, and it is not surprizing that the uneducated people of a few centuries ago

were terrified. To see the stars appearing in the middle of the day, to see the fowl go to roost, to see the wild birds circling in confusion, is a sight long to be remembered. As the wave or ripple-like shadows chase over the ground, and one experiences the sudden chill that comes with a slight tho rapid decrease in temperature, one cannot resist a feeling of awe. If one is located so as to see the edge of the shadow approach at express-train speed, the sight is even more inspiring. Then, after all is darkness, to see the sun suddenly burst out from the moon's edge in a wealth of splendor, makes one to feel in oneself something of the sun's triumph over its brief eclipse by the moon.

To the astronomer an eclipse offers an opportunity to study many things not ordinarily afforded him. He travels to a far corner of the earth and spends months preparing his apparatus and rehearsing over and over again the measurements he is to take. As only a few brief minutes are afforded for the work when the time comes, any error is costly. That particular eclipse will never occur again, and every scrap of data is valuable.

One of the things of major interest is the sun's corona. This is composed of luminous gases and extends out from the sun's surface for several hundred miles. Normally these gases are impossible of study because of the brightness of the

sun's disc adjacent to them. An eclipse offers an opportunity to study them without this handicap. Of recent years much interest has been centered upon the confirmation of Einstein's theory that light has mass. If this is so, the light from stars which must pass close to the sun on its journey to the earth should be bent toward the sun. Light from such stars, of course, cannot be seen when the sun is not obscured by the moon; but during an eclipse they stand out clearly. All the evidence so far collected points to the correctness of Einstein's theory, but there are so many factors which might produce a confusing effect, such as refraction of the light by our own atmosphere, that the conclusions are not accepted by all. Further data are desired.

The cause of the wave shadows that race across the earth during an eclipse is now understood. The shadows are produced by the changing temperature of the atmosphere, owing to the obscuring of the sun. Such temperature changes cause refraction, a bending of the light path, which produces the shadows.

The rate at which the sun's corona changes its shape is still an unsolved problem. So far, no two eclipse stations have been far enough apart to note this change and to measure the time required for it to take place. Of course, it changes from one eclipse to another, but these happen years apart. During recent eclipses attempts

have been made to measure this change, but without success. One or other of the stations usually experiences cloudy conditions. Doubtless in future eclipses more definite knowledge will be obtained regarding this particular phenomenon.

Man Marks Time

The exact measurement of time is the business of the astronomer. It is he who keeps our clocks correctly timed. Without him we might easily wander far from the correct values. In the early days of civilization the passing of time was marked by observations on the moon. The rising or setting of the sun one day was very much like that of another, but the moon's phases were easily recognized. Time was recorded, as a rule, by some simple method, as cutting notches in a stick. This was so in Egypt, in China, in Assyria, and with the American Indian. In the second stage of the development of the calendar, counting stages of five moons was developed. This was because the medium of trade and exchange was largely sheep and goats, and five months is their breeding period. As this wandered from synchronism with the seasons, the counting of six moons soon resulted—six for summer and six for winter. This coincided roughly with the year as marked by the sun.

The building of pyramids and obelisks, some writers believe, was due to a desire to measure

the year more accurately. Knowledge of the times and causes of the changing seasons certainly was a large factor in the superior agricultural position of the Egyptians, and the calendar thus determined was carefully guarded. Only the priests understood the measurement of the passage of time. It was they who announced the holidays, days of planting, and so on. In this way the farmers were not fooled by a few warm days into too early planting, neither did a backward spring mean that their crops were ruined at the end of the season. Among the Egyptians, not one person in 100,000 was ever allowed to see the calendar records. This jealously guarded knowledge gave Egypt an advantage over less informed nations.

The observations in Egypt were gradually replaced by more exact observations on the stars. Eventually a calendar was adopted having twelve months of thirty days each. The extra days of the year were devoted to a holiday period.

The conquest of Egypt by Julius Cæsar led to the adoption of a modified form of this calendar by the Romans. Alternate months were given an extra day to make thirty-one, except February. This month, which ended the year, had but twenty-nine days. This, while not as desirable as the Egyptian system, was a great advance for the Romans; for at that time their calendar was

three months off with the seasons, due to the falsification of records by politicians for the purpose of prolonging their terms of office.

Augustus Cæsar further spoiled this calendar by renaming Sextiles in his own honor and selfishly extending its length to equal that of the longest month—thirty-one days. A day was taken from February, thereby spoiling the quarterly system. It left the first quarter with ninety days and the third with ninety-three. This led to considerable juggling of the calendar. A day was taken from September and given to October. Then one was taken from November and given to December. Thus arose our awkward months, which are supposed by many to be as sacred as if handed to us by divine authority.

About three hundred and fifty years later the seven-day week was introduced, and the days were named for the first time. Up to 1582 the calendar was based on a year of exactly 365.25 days. At this time it was found that the accumulated error amounted to ten days. These were dropped between October 5 and 15 of that year, and our present leap-year rule adopted. The Protestant parts of Europe did not drop these days until 1752, when Great Britain and Ireland dropped eleven days in September. The Greek calendar, differing from ours by thirteen days, was used in some parts of the world up to 1919.

Our present calendar is indeed an awkward

affair. Neither its months nor its quarters are equal. Anniversaries, interest dates, and so on, fall on different days each year. The varying length of the months is perhaps the most annoying factor, however. There is a difference of eleven per cent. in the lengths of February and March, and a difference in the number of working days of 19 per cent. This leads to considerable difficulty in accounting, in comparison of month-to-month statistics. Especially does this raise difficulties for corporations that have most of their business falling on certain days of the week, as on week-ends, for example. Some months have five Saturdays, others have only four. This is decidedly awkward for concerns which pay their employees weekly and conduct their own finances on a monthly basis. All these things lead to heavy accounting expenses. There is a constant cost in providing new calendars and a loss of time in consulting them.

Because of these objections there has been agitation for calendar reform. It has been suggested that each quarter consist of two months of thirty days each, and one of thirty-one. Another suggestion has been that each quarter consist of three months of thirty days each, the extra day being undesignated and used as a holiday. A third suggestion would give us two months of four weeks and one of five weeks each quarter. The last and most favored suggestion is that the

year be divided into thirteen months of twenty-eight days each, a month to be called Sol being inserted between June and July. This would leave an extra day each year, which, it is suggested, would be called Year Day and have no designation other than that of the year. It would follow December, except in leap year, when it would follow June. This calendar, due to Moses B. Cotsworth, is known as the Cotsworth calendar. It is the calendar favored by the National Committee on Calendar Reform, and will probably be this nation's recommendation to the League of Nations Committee. The most suitable year to adopt this calendar would be 1933, the next year to begin on a Sunday.

III

THIS EARTH OF OURS

The Sun's Children Are Born

WHERE did the earth come from? What was its origin? How long is it likely to be here? All perfectly natural questions for the person to whom the answers may mean life or death. In the past we have had many theories as to the birth of this earth upon which we find ourselves, and many of them were extremely fantastic and imaginative—a fact not at all to be wondered at. As science advanced, such theories as the fall-from-infinity and the planetary-ring hypothesis were advanced. Then there were the theories of a star collision with the sun, and the nebular hypothesis. The latter was common in our school-books of the early twentieth century. Most of these theories have now been pretty well discarded, and while there are those who do not agree with the planetesimal theory as advanced by the late Thomas Chrowder Chamberlin, who was for many years head of the Department of Geology of the University of Chicago, it nevertheless has a sufficiently wide acceptance to justify its appearance here.

According to this theory, the planets are the offspring of the sun, their other parent having

been a star which, through chance, came into the gravitational field of the sun, and which is now, in all likelihood, cold and existent only among star wastage. This parent star did not form the planets by directly hitting the sun; but, being near the sun, it had the effect of drawing out from its molten surface in cone-like protuberances that material which was to form the planets. The actual birth of the planets was due to the propulsory power of the sun through eruptions, light push, radiation, magnetism, and electrical discharge—forces almost equaling its gravitational attraction—and the combined repellancy and attraction of other stars.

According to our latest knowledge of the dynamics of such occurrences, the cones pulled out from the sun would each result in a double explosion. A large mass would shoot out toward the star, and a smaller mass would shoot out from the opposite side of the star and travel in the opposite direction. Four such double explosions would form the four major and the four minor planets. Not having enough energy to pull these masses into itself, the star appears to have had sufficient to set them in motion on a near-circle around the sun. Dynamics also tells us that these planet bolts shot off the sun would emerge with a spiral and vortical whirl, which would later assist them in gathering around a

solid core. (The center of the earth is now believed to be solid, not molten, as long supposed.)

Without the passing star, the formation of planets from eruption of the sun would have been impossible. Normally, material shot off from the sun would be dispersed and would eventually fall back into the sun again. The star gave the erupted material great mass and a spiral motion, which made the formation of planets possible. The birth of planets such as ours can thus be the result only of the rarest kind of accident. It is estimated that the close approach of a star, such as seems to have occurred in this case, can take place on the average only once in a quadrillion years. On this basis another similar close approach, which might destroy our earth, is not due for an inconceivably long time. At the present time none of the stars seem to be headed in our direction. Our race will perhaps be wiped out by other circumstances long before this will occur.

The satellites are explained on this theory as offshots from the main bolt of matter shot out on each explosion. They are thought to be due partly to separate eddies or whirls on the outside of the molten planetary material, which were separated from it by the drag, and partly to secondary eruptions from the main mass. They succeeded in getting far enough from it to form their own cores, but not far enough to escape

from the gravitational field. They were thus held revolving around it. Abandoning the old theory that the moon presents only one face to the earth because of tidal influence, the new theory holds that this is because the moon is not symmetrical, but is heavier on one side than on the other. Gravitational attraction accounts, then, for this heavy side being always toward the earth. The same explanation is given for the similar behavior of Mercury and Venus, which always present the same side toward the sun. The strange behavior of some of the satellites of Jupiter and Saturn, which revolve around their planets in a direction retrograde to that of all others, is accounted for on the theory that their direction was reversed by a collision with the central mass. Failure of the nebular theory to explain this was its undoing.

"Nothing whatever has been found in the record to imply that the birth of the earth was a feature of the absolute beginning of the universe," says Professor Chamberlin. "The inquiry has led to the impression that the creation of our planetary system was but an incident in the history of our sun, while even the genesis of the sun might not improbably be but an incident in the history of our stellar galaxy." The birth of our earth was but a minor affair in the history of the universe, and it is quite unlikely, as Professor Chamberlin put it, "that

even the star neighbors felt any 'thrill' by reason of the event."

We Live on a Hot Steel Ball

What is in the interior of the earth? It is a difficult question to answer. Strange to say, we actually know more about the contents of stars millions of light-years away than we know about the earth on which we daily tread. The Abbé Th. Moreau, Director of the Observatory of Bourges, writing in *Le Petit Journal*, said: "In the present state of human industry we cannot think of exploring the earth's entrails directly. The greatest depth realized is that at Olinda, California. Rocks have been brought up from 2,460 meters below the surface. But what are three kilometers to the 6,371 which must be traveled to reach the center of the earth? A simple scratch."

Obviously, then, we must gain all our knowledge of the earth's interior indirectly. We have not at hand the mechanical means to penetrate far enough into the earth to do more than this. We find for our purpose but two sources of information. The first is the volcano, which has supplied us with valuable data, altho often at the most inopportune times and in a highly undesirable manner. The other is the temperature measurements made in deep oil wells.

Study of oil wells has shown that there is a

considerable increase in temperature with depth, tho the increase varies with the locality. In South Dakota the increase in temperature with depth varies from one degree Fahrenheit in forty-five feet to one degree in twenty feet. At Fairmont, West Virginia, a temperature of 175 degrees was found at the bottom of a 7,500-foot well, while at Longmont, Colorado, a temperature of 212 degrees was found in a 6,600-foot well. Based upon the temperature-rise of the last 1,000 feet of the seven deepest wells in the United States, an estimate of the temperature at the center was given by the publication *Tycos* as 443,000 degrees Fahrenheit.

That such a temperature is at all probable at the earth's center is admittedly preposterous. The temperature certainly could not go on increasing at the rate given. To measure the rate in the first three miles and assume that it continues is much like measuring the rate of growth of a child in its first few weeks and assuming that it will continue to grow at this rate until it is eighty years of age. In this way we would compute into existence a race of giants. The outside temperature of the sun is only 11,000 degrees Fahrenheit, and while its center may be much hotter, it is doubtful if the interior of the earth reaches a figure greatly above this.

If we go down to the birthplace of volcanoes, about twenty or thirty miles, and assume that

for this depth the temperature increase is at the rate observed in the previously mentioned deep wells, we shall arrive at a temperature high enough to melt lava—some 3,000 degrees. We might now assume that the interior temperature remained the same everywhere below this thirty-mile crust, as in a liquid, where temperature differences quickly smooth themselves out through convection currents. But the interior of the earth, from a study of its rigidity, weight, etc., appears to behave like a solid steel ball. This is quite possible, even at temperatures well above the melting point of the earth's materials, because of the enormous pressures which must exist inside. If, now, we regard the earth as a solid, a temperature equalization in the interior is decidedly unlikely. It would require centuries for a molecule at the center to wend its way to the surface. The interchange of kinetic energy, which is the temperature-controlling factor, between inside and outside molecules would be an extremely slow process.

On the other hand, there are those who believe that the interior of the earth is a cold solid. They believe that the temperature-change which is found as we go down in deep oil wells is due either to the presence of radioactive material or to chemical changes which are in progress in the oil. It happens that there is about enough radioacti ve material in the earth's crust to make

this a plausible theory. That there is some basis for the contention that the heat in oil wells is due to chemical action is also true. The rate of increase in oil wells with depth appears to be much greater than where oil does not exist. In fact, this has been suggested as a method of prospecting for oil. To account for the heat of the volcano, these people contend that the volcanic material is normally cold and that the heat is generated when pressure is relieved by rock-slippage. The reduction of pressure allows certain heat-producing reactions to go on, which at normal pressures are impossible. The heat is thus a local product of chemical action.

We are left with the obvious conclusion that we know but little of what is below the crust upon which we daily tread. Perhaps if we knew more of what is under us we should be less at ease.

The Age of the Earth

Man has long been curious enough to wish to know the earth's age. The earth has, on her side, kept the secret well. We can make our scientific guesses—no one can deny us that privilege—but after all we can reach only a very limited degree of certainty. In the end, the ingenuity of the methods employed is found to be of more interest than the results obtained. In all these guesses we are concerned with the age of the

earth, computed from the time the crust formed. We are not interested, for the moment, in how long it may have existed in the molten state, or how long it was previously a part of the sun.

The first of these scientific guesses to deserve our attention is that of Lord Kelvin. His estimate is based upon the present rate of cooling of the earth's surface. This gives an approximation of the time which must have elapsed since it was a molten mass. We can estimate what its temperature must have been at that time. Lord Kelvin's first conclusion was that the age was between 20,000,000 and 400,000,000 years. He later reduced the maximum figure to 40,000,000 years. This figure did not meet with approval of zoologists. They did not believe that it was long enough to have permitted of the great changes which had been found in animal life in the process of evolution.

Further estimates were obviously in order. A computation of the amount of salt in the ocean as compared with the amount poured into it annually gave the age as about 350,000,000 years. But who can say that the ocean did not originally contain some salt? Estimates based upon the rise of the deltas in the Nile and Mississippi Rivers—on the retreat of Niagara Falls—on the retreat of the glaciers in Sweden after the ice age—are likewise open to objection. There are

many factors which might have influenced these occurrences outside of time alone.

Our most modern method comes from the study of radioactivity. The parent radioactive material, uranium, like its children, goes on constantly disintegrating. In this process it gives off the primary electrical particles—electrons—and helium. As it looses this material it passes through transitions from one material to another and finally becomes radioactive lead. Here the process of natural transmutation stops. Nothing that man has ever been able to do has changed the rate of this process. He has tried the very extremes of temperature available to him, the highest voltages that he is capable of producing, but always failed to change the rate of disintegration in the slightest degree. It is safe to assume, therefore, that no changes on the earth's surface since its crust was formed have been of sufficient intensity to make any change in this disintegration rate. Assuming, then, that this rate of disintegration has been always constant, the percentage of lead found in a sample of uranium should give us the means of determining how long this disintegration has been going on. Such estimates indicate that the youngest rocks of the earth have existed for 1,000,000,000 years, and credit the earth with a minimum existence of from 2,000,000,000 to 8,000,000,000 years.

Writing in *De Telegraaf*, Professor W. J. Luyten compares the period of the entire existence of life on the earth to a day of twenty-four hours. On this basis he says:

"The greatest period, that is the longest life, must be accredited to the most primitive creatures in microscopic form. They lived twelve and a half hours by this time. The life of fish has lasted now for eight hours, that of reptiles two and a half hours. The mammals aren't supposed to have existed for more than three-quarters of an hour, and man only two minutes. When one considers that our 'civilization' began 6,000 years ago, then we must admit that it really makes up no more than four seconds of that entire day of life, and that our modern industrial period makes up only one-tenth of a second out of that day. However far man's existence may seem to date back as a 'civilized' creature, man has yet hardly been weaned."

Man Weighs the Earth

We may find ourselves balked in our attempts to discover what is inside the earth. We may arrive at a very indefinite conclusion as to its age. But there is one thing that we can do which at first hand would appear at least as difficult as either of these. We can weigh it. Archimedes is said to have claimed that, given a place whereon to stand, he could move the

earth. How many tons would it have been necessary to move? He did not know just what such a contract would have called for. We do. The weight is six thousand million million million tons. It is actually known more accurately than this, but the total given is approximately correct.

To ask just what good it is likely to do anybody to know this is a legitimate inquiry. It is useful for two reasons. It is one of the things that inform us, to some extent, of the earth's interior. We find that the rocks forming the earth's crust are from two to two and one-half times as heavy as water. The density of the entire earth as computed from its weight and size is twice this. This leads us to the remarkable conclusion that its interior is a solid iron ball, *which is further confirmed by the fact that other* heavenly bodies, meteors, which sometimes land on our earth, are so constituted.

Again, this knowledge of the weight of the earth is important to astronomers. In their study of stars and planets the weight of the earth is frequently of value—especially so in computing the weight, orbits, time of revolution, etc., of the other planets.

How can we weigh the earth? In principle the experiment is very simple, altho, in actuality, to obtain accurate results is exceptionally difficult. The simplest method is that of the pendulum. This method is used at the United States Bu-

reau of Standards. The experiment is performed by setting up what might be referred to as a miniature earth. Two large steel balls weighing 140 pounds are used as artificial earths. Between these steel balls two gold balls, weighing an ounce and a half and fastened at the ends of a light platinum rod, are suspended by a thin tungsten fiber. The gold balls are set swinging and their periods of swing measured. The weight of the steel balls and their distance from the gold balls determine the period of swing. So sensitive is this arrangement that the presence of a person as much as ten feet away will cause a variation. Because a car moving outside the laboratory would affect the precision of the result, the apparatus is located thirty-five feet below ground level. The attraction of the steel ball for the gold ball is only in the neighborhood of a millionth of a grain or about a thousandth of a milligram. By repeating the experiment with the steel balls at different distances the constants of the apparatus can be measured. It remains, then, only to determine the attraction of the earth for the gold balls and to know the distance between the center of the balls and the center of the earth. The problem is one of substitution in a proportion. The attraction depends upon the product of the two masses and inversely upon the square of their distances apart. Therefore the mass of the earth is to the mass of the steel

ball, as the attraction of the earth times the square of the distance between centers of earth and gold ball is to the attraction of the steel ball times the square of the distance between steel and gold balls. The arithmetic is simple. The experiment is rendered difficult by the necessity of putting the vibrating gold balls in a vacuum chamber to eliminate the effect of air currents, the necessity of avoiding vibrations, and by many other troublesome factors. The work at the Bureau of Standards is being carried to greater accuracy than exists at present by Dr. Paul R. Heyl.

IV

SURFACE DISTURBANCES OF THE EARTH

The Earth Has a "Blow-Out"

THERE are probably few experiences more terrifying, if one is to judge by descriptions, than to be in the neighborhood of a full-fledged volcano in eruption. Yet there is perhaps nothing more necessary than such eruptions when one considers the general good of all earth-inhabitants. A volcanic eruption is a blowing off of a great safety valve.

There is a decided sameness to all volcanic eruptions. Throughout the centuries volcanoes have belched forth the same kind of magma, and records of the temperature of this has shown it always to be within the narrow limits of about 1,000 to 1,500 degrees Centigrade. On the assumption that the interior of the earth was molten, this was difficult to explain. It was assumed that it all came from the same interior reservoir, the temperature and contents of which were the same throughout the time considered.

But now we know that the interior of the earth is solid. We know that there is a gradually changing condition as we go down. We now assume that at the depth of volcanic origin, twenty or thirty miles, there exists, not a reser-

voir of molten material, but a chemical and physical condition which gives rise to volcanoes. At this depth it is assumed that the materials are solid, not because of low temperature, but because they are kept solid in spite of the temperature by enormous pressures. These pressures we cannot hope to approach in the laboratory, yet at 20,000 atmospheres (about 300,000 pounds to the square inch) gasoline becomes as viscous as vasoline, and wax becomes rigid.

The condition which is immediately responsible for a volcano is thought to be a slippage of the rock formation, perhaps due to immense loads of sediment which accumulate on the ocean floor. The displacement of the crust by a mere fraction of an inch would result in enormous pressure changes within the earth.

With the formation of a fissure or crack in the rock which forms the earth's crust, there is at once afforded a means whereby the magma can begin to force its way slowly toward the surface. Throughout the journey the temperature remains high, because the rocks with which the effluvia come in contact are poor conductors, and also because there is still contact with the hot magma below. If the volcano is an old one, the rocks are already heated and the moving material falls very little in temperature. With the release of pressure the magma gradually be-

comes molten and eventually flows over the side of the volcano's crater.

In the case of an explosive eruption there are some other factors at work. First come great quantities of steam. This is due to the magma encountering water on its way to the surface. The explosive character of water which strikes a hot surface is well known. After the steam comes gas. About a third of this is hydrogen, one of the most explosive of gases. This is accompanied by phosphorus and other dangerous materials. In addition we may have profound chemical action between materials in the magma itself. Materials which under pressure in the interior of the earth might lie side by side without reaction may, when liquefied, become intensely active. Also the gases dissolved in the magma may rush to the surface, giving the effect of opening a giant bottle of carbonated water.

As a result of this explosive action we find stone so inflated with gas-bubbles that it will float—pumice-stone. We find the lava blown to a fine dust, which sometimes obscures the sun. This dust has been known to spread in the upper atmosphere around the entire earth, and, by shutting off some of the sun's rays, to lead to a cold period lasting several months.

Accompanying the eruption there are usually earth tremors. These might well be expected,

both because of the violence of the eruption and because of the origin of the eruption as well. Severe lightning storms also are common during an eruption. This may well be due to the electrification of the lava dust and of the gases as they are shot upward through the air. Electrification will result from the friction between the gases.

After an eruption has subsided there is still danger left. This is in the poisonous gases that are given off. Sulfur gases appear first. On further cooling, water vapor, hydrochloric acid, sulfureted hydrogen, and chloride of ammonia are given off. Finally carbonic acid is given off, and this, being heavy, collects in valleys and low-lying ground. It results in the so-called poison valleys. Some volcanoes have a predominance of the one or other of these gases.

A volcanic region eventually becomes one of geysers and hot springs.

The Earth Shakes

The cause of earthquakes is like that of volcanoes—rock slippage. If we were to investigate it further it would lead us to an examination into the cause of the slippage itself. Of this there have been many theories. One has it that the slippage is due to an actual shrinkage in the earth's surface as the earth gradually cools inside. Then there are those who believe that

earthquakes are due chiefly to the piling up of sediment on the ocean's floor, resulting eventually in such a load that the crust of the earth can no longer support it without some readjustment. This results in a series of disturbances. Others would suggest that earthquakes result from earth-tides, which gradually mold the earth's surface until it reaches a point where a sudden crack or slippage takes place. Others claim to see a close parallel between the sun-spots and periods of earthquakes. Just how a sun-spot could so profoundly affect the earth's crust is indeed difficult to see, and yet data have been found which indicate a parallel between these two phenomena. Perhaps we may be more nearly on the safe side if we suggest that all these things may contribute to the beginnings of an earthquake.

The one bit of earthquake information that is least known to the layman, apparently, is that earthquakes in any locality are almost continuous. The earth is almost constantly trembling. At any seismological station large numbers of quakes are registered daily. Most of these, however, cause no more vibration than is caused by a truck a block or so away. They are easily distinguished from the latter by the trained seismologist with the aid of his sensitive instruments. At the same time there are few days when a seismic station does not register what

is called a major quake—one of sufficient intensity to give data worth communicating to other stations.

In addition to the almost constant trembling of the earth there is also often indicated a tilting of the earth. This is, of course, a local effect, thought to be due to the piling up of great masses of water on the beach at high tide. The same local tilting can be observed when a large number of persons visit a seismic station. The tilting is extremely slight, and only the very sensitive instruments of the seismic station would be capable of detecting it.

It is enough to say, perhaps, that a few hours at a seismic station watching the records would convince any one that this earth is not the solid, steady planet which we ordinarily think it is.

Exploring the Atmosphere

Surprizing as it may be that we know so little about the earth beneath us, it is equally, if not more surprizing, that we know so little of the atmosphere above us. We do not even know how high it extends upward from the surface of the earth. Confronted with the question, one usually answers thirty or forty miles. It is difficult to find any justification for such an estimate. The answer probably depends upon what we mean by the earth's atmosphere. Would it be correct to say that it extended only to that

distance inside of which it is capable of supporting life? Then it extends only a few miles, perhaps three or four. Or should we define it as ending at that point at which no gas is present? To estimate where this would be is quite impossible. And yet if this is not the point at which it in fact ends, then it is difficult to select any other more suitable point.

Suppose we decide to say that the atmosphere ends where pressure-gauges, regardless of their sensitivity, no longer register any pressure. The pressure is zero. How can we determine where this point will be? Certainly we cannot reach it by airplanes, dirigibles or balloons. To go up even threc or four miles an aviator requires enormous preparation. He must carry oxygen to breathe, electric heaters, both for himself and to vaporize the gasoline, and so on and so on. The intense cold and the rarity of the atmosphere make it out of the question to attempt to go much higher than this. Dirigibles and balloons are even more hopeless. They depend upon the buoyancy of the air to lift them, and, as this air becomes rarer at high altitudes, they are unable to rise. Perhaps rockets, which do not depend upon the air but are in fact hindered by its friction, will eventually be used to explore the upper atmosphere. In the meantime we must depend upon computations.

Now, computations of the height of our at-

mosphere are extremely difficult to make. There are many factors which complicate the problem. The air is composed of many gases, it is compressible, and it has weight. The rotation of the earth is another troublesome factor. Further, the temperature of the atmosphere is different at different levels. The particles of gas are always in violent agitation.

The only data that give us much assistance are those of atmospheric pressure. Air, tho very light, has weight, and there is enough of it above us so that, due to its weight, there is a pressure upon us of about fifteen pounds per square inch. Our bodies are made to withstand this pressure, and if the atmosphere were suddenly removed we should doubtless explode. If it had no weight there would be nothing to hold it to our earth, and it would soon disappear into space. As conditions are, it would be necessary for a particle to acquire a velocity of 25,000 miles an hour to escape from the earth.

If temperature were the same at all heights and we had but a single gas to deal with, we could at once compute its height from its weight per square inch on the earth's surface. But it is composed of several gases and we do not know how much of each. It takes an eight-mile column of hydrogen to weigh as much as a single mile of oxygen. Then, too, there will be variations in

the temperature as we go up, a factor of which we know almost nothing.

We know also that if we rapidly rotate a wet ball, the water will collect around its middle, or equator, and will fly off from this belt. In the same way our atmosphere tends to collect at the earth's equator. The air-layer over the earth is thus greater at the equator than at the poles.

Why should the temperature fall off as we go up? It would appear that the sun's rays would be stronger higher up, as they have not been absorbed by the atmosphere as much as have those which reach us. The answer to this is that most of our heat comes from absorption by the ground. Many of the sun's rays absorbed by the earth are reemitted as heat only to be again absorbed by the atmosphere within a few meters of the earth's surface. The atmosphere thus acts as a blanket to keep the heat in. The effect is much like that of a hothouse. If it were not for this blanket the temperature of the earth would be about sixty degrees below zero.

It is also sometimes difficult to see why the air, having weight, does not fall at once to the earth. Failure to do so is due to the rapid molecular motion of the air particles. These particles have a trembling motion of enormous velocity. They are constantly striking and rebounding from each other. The velocity of oxygen at normal temperature and pressure is about a quarter

of a mile per second. Hydrogen has a velocity of about a mile a second. It is the impact of molecule against molecule at this enormous velocity which holds them apart and in the gaseous state. If the temperature were reduced so that they slowed down they would fall to the earth as a liquid. Or if they were slowed down to an even greater extent, the earth would be covered with but a few feet of solid air. To accomplish this a temperature of nearly 460 degrees below zero Fahrenheit would be required.

In spite of all the information which we have concerning gases, we must still admit that we know very little about the atmosphere above us.

Major Earth Winds

In a study of the earth's atmosphere we are also confronted with the regular air currents or winds which keep it in a state of constant motion. Chief among these steady winds are the so-called trade winds, which are to be found at the equator, and with which every school-boy is familiar because of their important bearing on the voyage of Columbus. Then there are the prevailing westerlies with which we have all recently become familiar because of the obstacle they present to east-to-west trans-Atlantic flights by airplane. Both of these familiar air currents are due to the same cause.

Every one knows the fundamental principle

of physics which says that heated air, because it is rarer and lighter than cold air, rises. It is this fact which is put into practise in hot-air furnaces used in small buildings. Now the air at the equator, being heated, will rise, and air from both north and south must come in to take the place of this air. Having risen, the air is away from its source of heat, which is the radiation of heat due to absorption of sunlight by the earth. It consequently cools and falls again, farther north. Part of it will again blow toward the equator, while part will continue north.

Now, if the earth were stationary this would result in north and south winds only. But the earth is rotating. It is often believed that it is this rotation, dragging the air after it, which gives the wind its easterly direction at the equator. If this were the case, all winds should have such a direction, while as a matter of fact the winds in the temperate zones are westerly in direction. The true cause for the veering of the winds from straight north and south is a gyroscopic action due to the earth's rotation. The peculiar behavior of such action is easily imagined by any one who has ever played with a gyroscopic top, a toy which behaves in a most uncanny fashion. The principle which determines the direction of the winds is utilized commercially in the gyroscopic compass.

The result of the convection currents and the

gyroscopic action is a wind blowing toward the equator in a southwest direction, north of the equator, and in a northwest direction south of it. As the air which rose at the equator falls again in the north and south hemispheres, there is created an almost windless region in each, known as the doldrums. North of this, in the northern hemisphere, the wind has a northeasterly direction, and in the southern hemisphere, south of the quiet region, the direction is southeasterly. In addition to these main winds there are the circumpolar winds.

While local disturbances close to the earth do not always permit these winds to be recognizable, their presence is none the less obvious. If one observes the cirrus clouds, which are several thousand feet above the earth, one will find that in the northern hemisphere they are always traveling toward the east. Their velocity is usually from twenty-five to fifty miles an hour. It is the existence of these winds upon which our whole system of weather prediction is based. That their velocity is not great is due to friction with the earth. Were it not for this factor the velocity of the wind would probably reach thousands of miles per hour. In the southern hemisphere, where the obstruction by land is not great, these winds do in fact reach considerable velocities. Their intensity at about the fortieth

degree of latitude, in the southern hemisphere, has resulted in the phrase "the roaring forties."

A complete study of our winds has yet to be made. At present we know only what is happening near the earth. Air cannot always blow in one direction. It must get back somehow. Thus, while the wind is somewhat toward the north at all points in the northern hemisphere, it certainly does not pile up at the pole. There must be counter-currents higher up. Perhaps if we knew where these are, airplanes might cross the ocean as easily from east to west as from west to east. It is thought that such a current may be sandwiched in as a narrow ribbon from 6,000 to 10,000 feet over the Atlantic.

The airplane now demands a more thorough study of these air-currents and this study will doubtless be made through the release of small sounding-balloons. At the present time we are surprisingly ignorant of all but the most obvious.

Weather Prediction

All clouds are the result of the condensation of moisture from the atmosphere. At any particular temperature there is a limit to the amount of water which the air can hold, and any decrease in temperature will immediately result in condensation and the formation of clouds.

In warm places there will be formed convection currents of air which rise rapidly and carry

with them the moisture due to evaporation from the ground. As these currents reach the cooler regions higher up the moisture will condense to form a cloud at the top of the column. Such a cloud will be a cumulus cloud, one of the large billowy kind which one so often sees floating lazily across the summer sky. Such clouds are fair-weather clouds and bring rain only when they have reached an abnormal thickness. This thickness will depend upon the temperature. In winter a thickness of about 300 feet will bring precipitation, but in summer the thickness must be much greater than this to bring rain.

The formation of these clouds by the rush of air upwards results in a region of low barometric pressure. As these regions are formed, usually only on a large scale on our west coast, winds from the northeast and southwest rush into the low-pressure area, causing a vortex motion. In the northern hemisphere the winds circle around this area in a direction contrary to that of the hands of a clock if one is looking down on it. This region of low pressure is carried across the country by the prevailing westerly wind. From its travel one can thus predict with considerable accuracy the arrival of low pressure for any locality. This is the basis of our system of weather prediction.

Sometimes a cumulus cloud will become greatly overgrown and thus a cumulo-nimbus

V

MAN

Man Inherits the Earth

THERE are two schools of thought in regard to man's origin. There are those who hold that man has evolved from the lower forms of life which resemble man—the ape and his progenitors. On the other hand, there are those who hold that man has evolved separately from those forms along a distinct line; that there is no direct relation between the ape and man; that man has existed in a form resembling that of to-day since the beginning of our geologic record of about 400,000 years.

The reasons for the first view—that man is a direct descendant from some ape-like form—are obvious even to the layman. There is unquestionably a close resemblance between man and the ape, and upon careful study this resemblance becomes even greater. The difference is so slight as to fool the experts. Skulls recently found in Bechuanaland were at first labeled as those of apes and later relabeled by the ethnologists as those of men. The line of demarkation between early man and the ape is extremely slight.

Let us consider some of the evidence offered by the geologic record for the second point of view.

Going backward from our time, which we shall call the Recent Age, we reach the beginning of the Ice Age. The Ice Age, more correctly known as the Pleistocene Period, was not a period of continuous glaciation. It was a period of alternate hot and cold. There were, in fact, four ice periods, separated by much longer periods of higher temperature. Before this time was the Tertiary Age, the last division of which is called the Pliocene Period. This description follows the American nomenclature, which differs somewhat from that used in Europe.

Most of the animals which lived in America before the first glacial period are now extinct. Probably this is due to the severity of that period. Some, however, survived the extreme conditions. Horses, camels, and peccaries seem to be of this group. When the warm period came—the Aftonian—many animals came to America across Bering Straits, an overland route, as the continents were not then separated. This migration included such animals as elephants, lions, tigers, moose, deer, bears, dogs, and many smaller animals. Others are thought to have come in from South America—many strange forms which no longer exist, as well as those still characteristic of that continent. It is thought that fully one-third of the animals of that period are still to be found, the other two-

thirds having been wiped out by the succeeding three glacial periods.

Has the process of evolution changed these animals notably? Dr. Oliver P. Hay, of the Smithsonian Institution, writes:

"The numerous horses of the Aftonian became extinct, but some of them, as shown by their skulls and skeletons, differed from our domestic horses so little that the experts can hardly tell the difference. The abundant camels of that time have their counterpart in the camels of the old world and the llamas of South America. The elephants would be recognized as such by any child who had witnessed a street parade of a circus. It is evident, then, that evolution, which produces all natural changes in animal form, has effected little in the perhaps 400,000 years since the Aftonian stage. A learned writer on mammals tells me he doubts that a single new species has been developed since the first interglacial stage. The great changes in the animal life in this country have been due, little to evolution of new kinds of animals, but almost wholly to the extinction of the many especially large and striking forms."

Animals have changed little if at all in this long period. Now, what do we know in regard to man? The discussion here must center around the Neanderthal man, who appeared a little before the middle of the last glacial period. His

appearance can only be described as ape-like. He had the curved spine and walked in the stooped, bent-kneed position characteristic of the apes of the present day. His skull was flattened at the back, his jaw protruded into what might be called a muzzle, resemblant of the features of the lower mammals. His receding chin and forehead sloped back to such an extent as to be hardly worthy of the names. He had a broad flat nose and large eye-sockets. He was distinctly ape-like, but was he ape or man? He has been described, so far as appearance is concerned, as about three-fifths man and two-fifths ape. But let us see how he may be regarded.

First of all, the Neanderthal "man" may be considered as a link in the chain from ape to man. It has been argued that he is the direct progenitor of the Cro-Magnon race, which appeared during the latter half of the last glacial period, and which is easily recognized as belonging to the human race. That this could be true is doubtful. It requires that we believe that in the course of a few thousand years man underwent a far greater evolutionary change than have any of our animals in the entire period of about 400,000 years since the beginning of the Pleistocene Period. This is difficult to believe. Marcellin Boule, the French anthropologist, in his book, *Fossil Men,* writes, that this would be "a mutation so great and so sud-

den as to be altogether out of the question." It may also be pointed out that at this same time there lived in the same vicinity as the Neanderthal man a race which resembles very much our present negro. It is difficult to believe that such vast changes should have taken place in the Neanderthal man and left the progenitor of the negro, the Grimadi race, untouched.

We are left, then, with the alternative that man existed in the Tertiary Period, before the Ice Age, in much the same stage as he is found to-day in the uncivilized parts of the world; that he, like the animals, has evolved but little since that time, the degree of evolution being shown by the differences which now exist in the various races found in different parts of the world. This, of course, leaves us with several things unexplained. Why do we find no evidence of his existence during these early periods? How can we account for the sudden appearance and equally sudden disappearance of the Neanderthal man, and his immediate succession by the Cro-Magnons?

The problem is baffling and may never be solved. Nevertheless, scientists will keep on trying to find a clue to the mystery. It is detective work carried to the *n*th degree. Every part of the earth is being scoured for evidence. Expeditions are constantly searching the most out-of-the-way places, risking hardships, dangers, and

possible death in the jungles for a tiny scrap of evidence to piece out a solution of the mystery. Every scrap of possible evidence, when brought back to civilization, is weighed and reweighed, analyzed and discussed, to obtain from it every bit of meat that might be of value.

It is indeed unfortunate that these men, whose interest is only in the facts they find, and who are willing to change their views as each new scrap of evidence dictates, should be hampered in their work by interference on the part of those who are not fully informed as to the true purpose of the work, and should of necessity spend part of their time in fighting damaging legislation which prevents, in many places, a free discussion of their findings. That this is so is unquestionably due to a lack of public knowledge of the subject, and will doubtless be overcome by the wave of popular interest in science which has recently been aroused throughout the world. We may be sure that the work will be pushed to the limit of human ability and that almost any time startling discoveries may come out of the heart of Africa or from some other little-known region of the earth's surface.

The Horde Instinct in Man

In the matter of man's sexual matings and the origin of the present essentially monogamous social system, there are, as might be expected,

various theories. It was long the popular belief that the present system developed from a horde system which resembled that of the lower animals; but of late this thought has been largely abandoned, because no primitive tribe has been found in which such a custom prevails. True, there have been found tribes in which promiscuous relations are permitted in early youth, and others in which several matings may be made during a lifetime; but the social system is, nevertheless, in both cases essentially monogamous. The tie between male and female at least continues during the child-bearing and early rearing period. The behavior of these people may be described quite readily in terms of that of many of the people in the more civilized countries of the world to-day.

Another reason for our difference in social life from that of animals, that has been suggested, is that none of the animals have an ever-present mating instinct, as has man. The mating instinct in animals is dependent upon the seasons or upon some physiological change. Man, as has been supposed, is the only animal in which this is not the case. This, however, has been found to be untrue. The mating instinct has been found, by observation, to be the same in monkeys and apes as it is in man. It is neither seasonal nor dependent upon physiological changes, but is ever present. This is a conclusion reached by

no less an authority than Professor Robert M. Yerkes, of Yale University, who during the last fifteen years has conducted a series of brilliant experiments on the habits of these animals. He has found that the mating instinct is ever present in them. Unfortunately, his findings have been largely overlooked by anthropologists.

If this social factor, ever-present mating, is the cause of our monogamous system, then evidence of at least the rudiments of a similar system should be expected in the life of monkeys and apes. Such is not the case. The monkeys are found to live in hordes and to follow the horde system of sexual relations. There is no evidence of monogamy. There is nothing resembling the family ties of the human race.

That the horde instinct is present in man is everywhere in evidence. One does not need to present a statistical study of violations of accepted social behavior to prove this point. It will be readily accepted. Not only are violations of what is considered proper social behavior common, but it goes without saying that there are many who are held in check only through the fear of social ostracism if the misbehavior is found out. If, overnight, all of our social taboos could be swept away, there is little doubt that the outcome would certainly tend strongly toward a horde system. The fact that the Great War did in reality sweep away many of these

traditions at one time constituted a real menace to our social system. The fact in itself, that most of our social taboos are obviously intended to check the horde instinct, is evidence that a real danger to society exists in this possibility.

The reasons given by Dr. Gerritt S. Miller, Jr., curator of Mammals of the Smithsonian Institution, for the development of our present social system are, first, the human ability to form enduring association between partners and thus make sex-love a socially effective force; second, the fact that only in the human race can the female be forced by the male; and last of all, man's property sense, only the merest rudiments of which are found in any of the animals. "All of these facts seem to justify the tentative conclusion that those of our customs which center about the family are best explained as a modified horde life not yet completely adjusted to civilization's needs," says Dr. Miller. "When the process of change began we do not know, but it was doubtless at a time so remote that no present-day race of men had come into existence. The breaking up of the old horde may be conceived to have taken place under the influence of the specially human characteristics of mating psychology, which have just been mentioned, combined with and directed by man's rapidly growing property sense."

The Origin of Speech

It is difficult to conjecture as to the origin of speech, but one possibility that deserves consideration is that speech arose from pantomime with the lips and tongue. The idea is far from new, and appears to have been suggested by Socrates. An extended paper along this line of thought was presented before the Royal Institution by Dr. J. Rae as long ago as 1862. Later the idea was fostered by Charles Darwin, and as well by his noted rival, Alfred Russel Wallace. Recently this possibility of the development of language has been given much study by the English scientist, Sir Richard Paget. He has pointed out that emotion in the insect world is commonly expressed by sound, as in the love songs of crickets and birds. Pantomime is also used by birds and insects to convey ideas. Bees inform their colleagues of good finds by the honey and pollen dances which were first observed by Professor von Frisch of Munich. Warblers and the crested grebe present samples of nesting material as a courtship gesture.

Sir Richard Paget has pointed out that in archaic Chinese, in ancient Sumerian (as spoken at Ur of the Chaldees), in the Aryan and Semitic languages, and even in Polynesia and the west coast of North America, the same root words occurred—made by the same descriptive tongue

gesture—as, for example, the upward movement of the tongue which produces the word "al," meaning high, strong, protect, or rise. In support of his contention Sir Richard Paget has also pointed out that the descriptive words formed by children when they attempt to explain something for which they do not know the usual words, follow this rule. He also points out that the greater use of the hands in talking by the southern over the northern races is due to the fact that the northerners lived a harder life. They worked more with their hands and thus had them less free to use in descriptive pantomime. They were compelled to make their gestures with the mouth and tongue. Such gestures would, of course, be accompanied by a grunt to attract attention, and the sound of this would be influenced by the position of mouth and tongue and would in time be recognized, without visual observation, by the person addressed. To support the contention that all vocal sound is merely made by grunts modified by mouth and tongue positions, Sir Richard Paget has presented to skeptics an artificial vocal apparatus. A vibrating reed produces the grunts, always the same, and these are modified into understandable words by manipulation of the parts corresponding to mouth and tongue. His theory is well supported and somewhat convincing.

Why We Behave Like Human Beings

Why we behave like human beings is a problem over which the psychologists have long wrangled. What is it that makes any of us behave as we do? Are our acts predetermined before we are born? Are our destinies governed purely by external circumstances over which we have no control? Are we in any sense masters of our fate?

It is obvious that there are many answers to the questions asked. There are many possible viewpoints. Noted psychologists have taken the stand for one or the other of these possibilities and have defended them against all others; they have insisted that one or the other was the important factor. A more sensible viewpoint, however, must be that each and all of these are important; that one may, of course, be more important than another; and which one may be the most important must of necessity differ with the individual under consideration.

When one has read the section of this book dealing with heredity and environment, much will be clear without further comment. The method whereby nature transmits individual characteristics through the chromosomes makes it a foregone conclusion that, except in the case of relatively rare mutations, the nature of the offspring must be a composite of the character-

istics of the parents. Its traits must be those traits which have previously existed. Thus it is that mental capacity, predisposition to crime, musical talent, and all the characteristics that one could possibly think of, are definite things which are transmissible. It cannot be denied that, under the same set of conditions, two individuals, one with musical ability and the other without, would possibly react very differently. All beings are not born free and equal. Different talents must determine different behavior, regardless of environment and other determining factors.

The second great factor in behavior is environment. This factor includes a wide range ot things. It includes companions, food, opportunity for education and the development of special talents. That food is an important factor in the progress and the behavior of an individual there is much evidence to verify. That the influence of parents, companions, etc., is strong likewise cannot be denied. The inclination to imitate the action of others, so common in children, is evidence of this. Education is likewise of recognized importance, and other factors are, in general, also effective.

But all of these things are not enough to account for all individual behavior. Persons well endowed are often found in the ranks of human failures. There is something which must come

from within. Possibly what comes from within merely reflects what is without, as many contend. Nevertheless, there are those human complexes which are difficult to classify as due to anything other than the action of that particular brain.

"In earliest childhood," says Dr. Alfred Adler, "our physical inequality results in a normal feeling of inferiority, which reappears at intervals throughout life as we face each new series of difficulties. It is the motivating cause behind all constructive action.

"To counterbalance this feeling of inferiority the child early invents a goal of superiority, a way in which he strives to excel," says this authority. "Just as his body develops towards its final physical form, so his mind creates an ideal final form toward which every effort, thought, and movement tends, consciously or unconsciously, and despite every obstacle.

"To know the goal the mind has selected is to understand at a single leap the whole network of thought and action which is the 'behavior pattern' of the individual."

Behavior patterns are formed within and not without the individual, for this great psychologist adds:

"The only true and adequate compensation for our normal feeling of inferiority is the consciousness that we are part of all humanity and

of its accomplishments. It is this sense which makes for great achievement, useful and happy lives. No one can determine for another the direction in which he will walk, but the child can be helped to understand the choice he has to make and to choose the goal of superiority which fits into the social scheme."

It is obvious that failure to make the proper adjustment to our social conditions is the cause of many if not all of our so-called human failures. A child may be endowed with every opportunity which would lead him to the correct attitude, but failure to arrive at it would be fatal.

The subject of human behavior is an important and interesting one for us to-day. Failure to solve and control its causes is resulting in an ever-increasing drain on civilization. The criminal and the insane are unquestionably on the increase. The problem demands the united efforts of the best brains the world is capable of mustering.

Man's Changing Social Life

That social habits are reflected in our occupations there can be no doubt. A nation is an agricultural nation if a large proportion of its inhabitants are farmers; it is a manufacturing nation if a large percentage of its people are engaged in factory work. Professor W. F. Ogburn,

using this basis of analysis of the social trend, has but recently published some interesting data in the book, *Social Changes in 1928*, which has been printed by the University of Chicago. The number engaged in the silk industry is increasing more rapidly than the number in the cotton industry. The white-collar class is increasing more rapidly than the labor class. Domestic servants are decreasing, while waiters are increasing. Dentists have increased four times as fast as the population since 1850. In the same period plumbers, steam and gas fitters have increased 11,000 per cent. Barbers, hairdressers and manicurists have increased eight times as fast as the population. Chauffeurs and candy-makers are rapidly increasing. Social and welfare workers increased from 16,000 in 1910 to 41,000 in 1920.

From 1900 to 1920 the total population increased 39 per cent. and the urban population 49 per cent.; yet the number of waiters increased 113 per cent., and during the latter part of the period the number of restaurant-keepers increased 158 per cent. Delicatessen dealers have increased about three times as fast as the population since 1910, and employees engaged in canning and preserving fruits increased 37 per cent. in the period 1914 to 1925, despite the increased use of machinery.

It is not a difficult matter to draw conclusions

from such statistics. One of these, which cannot be controverted, is that our family life is changing rapidly. The increase in canners, waiters, restaurants, and so on, indicates clearly that the nature of the home is undergoing a revolution. Its old occupations are disappearing. Our standards of living are likewise changing. This is reflected in the increase of those in the luxury occupations—chauffeurs, candy-makers. hairdressers, and plumbers.

It is evident that our amusements are likewise being taken out of the home. They are being commercialized. In other ways the family life is disappearing. Many of the functions of the family are being taken over by the state.

Many further deductions could, of course, be drawn from these and similar data. Many of them would doubtless be debatable. We leave such deductions to the reader; likewise the question whether or not such changes are desirable. The subject holds much of interest to the thoughtful.

Final Earth Population

One of the favorite topics of discussion in the study of man's possible future is the speculation as to when the earth will have as many inhabitants as it can hold and what will happen after that limit is reached. It is not the purpose of the author to speculate upon the question

here; but an outline of the factors affecting such calculations cannot be out of place.

Those who have studied this subject necessarily take the possible production of food as a basis of estimate. The earth cannot hold more individuals than it can provide food for. In the past this food production has been based upon the known acres of land under cultivation and the number necessary to support a human being. Allowance has frequently been made for increase in agricultural efficiency. In the past such an allowance has, for the most part, been greatly underestimated. No one foresaw, at the beginning of the twentieth century, the increased agricultural efficiency of to-day. It is fair to presume that the same would be true of present predictions. Nor has the possible farming of the ocean (five-sevenths of the earth's surface is under water) been given reasonable consideration. These are all factors which cannot be intelligently estimated.

The decreasing birthrate is likewise a factor of great importance. It may keep us well away from any approach to saturation numbers. A study made by the Department of Economics of the Brockings Institution in Washington, which covered Great Britain and Ireland, France, Belgium, Holland, Switzerland, Germany, Denmark, Norway, Sweden, and Finland, together comprising over ten per cent. of the earth's

population, indicated that already the population is not only failing to increase but has a virtual deficit of about seven per cent. If this were true generally, saturation conditions would never be reached. But it is not. There is an increase of about five-eighths of one per cent. a year over the entire world. "If this rate were to persist, there would be a doubling of population in 110 years," says Professor Robert R. Kuczinski, of the Berlin Handelshochschule. "At present the total of human beings on the face of the globe is somewhere between 1,700,000,000 and 1,900,000,000. But the earth's capacity is limited by the potential agricultural resources, and, assuming that there are 15,000,000,000 acres of arable land and that 1.5 acres on the average are sufficient to support an individual, the maximum population would have to be placed at less than 10,000,000,000. Even allowing for all conceivable advances in technique, and assuming that all human effort will be directed to the maintenance of a maximum number of people, it seems impossible that the earth could sustain more than six times its present population, or about 12,000,000,000 people." Such is the view of an expert who has given much study to the subject.

VI

THE FIGHT FOR LIFE

The Battle Against Disease

THE struggle against disease is won. Most of the advance which medicine will make in the future will be against old-age ailments. We no longer think that germs originate in dirt and filth. The germs must get there from some one affected by the disease. We no longer think that germs are carried in the air. We do not cross the street in passing a house isolated because of some communicable disease. We know where to look for troublesome bacteria. Since Pasteur, in 1877, first demonstratcd the existence of living bacteria in the case of anthrax, most of the disease bacteria have been identified. The situation cannot be better summed up than in the words which Colonel H. V. Wurdeman used in a radio address:

"Our whisky has been mostly taken away from us, diabetes is cured by insulin, syphilis by salvarsan; tuberculosis, typhoid, diphtheria, by inoculation and serums; smallpox by vaccination. Even thc common cold, the forerunner of many deadly diseases, is amenable to serum treatment. The people generally know these facts and seek early treatment. Sweeping epidemics

of smallpox used to take off ten per cent. of our ancestors. Now no one should die from it; in fact, no one can take it if properly vaccinated. In my early practise 50 per cent. of children with diphtheria died, now only six per cent. There should be no more typhoid or other such diseases as were common up to twenty-five years of age. We know the menace of the house-fly, the flea, and the louse."

With this summary of present conditions, what may we expect of the future? The bacteriologist has been with us for some time, and he has accomplished much. Latest developments indicate that the time for assistance by the physicist and the chemist has arrived. The increasing use of the x-ray and of radium in the treatment of cancer is one application of the tools of the physicist. In addition we also find important research under way to determine the value of short radio-wave treatment. High-frequency oscillations between 60,000,000 and 70,000,000 cycles per second have been found effective in reducing tumors in rats. The new and powerful cathode-ray tube gives promise of a development which will make it the equivalent of tons of precious radium. The therapeutic use of ultra-violet radiation has become so general in the last few years as to be considered almost a fad.

The chemist is likewise making valuable con-

tributions. Not long ago, if a medicine cured it was considered satisfactory. Now the chemist wants to know just what it is in the medicine which cures. No sooner was the beneficial element in the irradiation of certain foods suspected than the chemists isolated it. It is ergosterol, a substance so potent that a piece much smaller than a pinhead per day is enough to prevent rickets. It is more potent than a pound or two of cod-liver oil.

Dr. William J. Mayo, speaking before the American Chemical Society recently, said: "Day by day a new conception of medicine brings forth basic facts which enable us to look on man as a chemical unit as capable of analysis as material in the test-tube. The study of vitamins, of hormones, of endocrines, and the electric concept of the nervous system are but a few of the outstanding investigations which are too recent for analysis." In closing his remarks Dr. Mayo further said: "Life is largely a matter of chemistry. The advancement of medical science began with those things which could be seen with the eye, the eye aided by a microscope, and has now progressed into the ultramicroscopic field of chemistry. In its modern conception, therefore, medicine has become a branch of applied chemistry." We are well on the way toward a complete defeat of disease.

Rejuvenation and Revival of the Dead

Along with the notable advances that have been made in medical treatment have gone equally notable gains in surgical practise. We may now say that almost the entire human body is subject to surgical treatment; almost every part may be reached by the surgeon's knife.

This being the case, it would appear that there was little advance to be looked for in this field of science. Such is not the case; the advance here has been as notable in the last few years as in any field of medical practise. This has been largely due to the adoption of new methods from the biochemical and physical fields. The introduction into surgery of the new electro-surgical units, which might be called electrical knives, has done much to alter and to refine the technique of the surgeon. In particular this device has proved its value in operating on certain forms of brain tumor, greatly simplifying the procedure. There can be no doubt that there will be a rapid extension of the use of this new instrument, which may in effect revolutionize surgical practise, even tho it does not extend the surgeon's field.

Recently medical treatment has taken over some of those things formerly wholly treated surgically. But since the reverse is also true, the surgeon has maintained his ground. One of the

transfers of the first-named class has been in the treatment of pernicious anemia. The frequent transfusions of former days have been superseded by the liver diet. But while this would appear to be a loss to surgery, we have the counterbalancing fact that diabetes is no longer a handicap to the patient requiring surgical aid. It has also been found that Raynaud's disease and Buerger's disease, once thought to be entirely in the field of medical treatment, are subject as well to certain surgical aids.

The manner in which the physicist can be of aid to the surgeon is well illustrated by the introduction of the artificial voice-box. In cancer operations which require the removal of the larynx, the patient in the past has been condemned to silence for the remainder of his life. Removal of the larynx means removal of an essential part of the voice mechanism. Now an artificial larynx can be used and the patient can speak clearly and loudly. It is even possible for such an individual to address successfully a large audience.

The cause of cancer has long baffled medical science, and altho some unanimity of opinion regarding its cause seems gradually being arrived at, no form of medical treatment has as yet been found. The field of cancer cure is left to the surgeon and to treatment by x-rays and radium. Of these methods, that of the surgeon

seems at the present time to hold the major place. If taken in time, this method has proved successful.

Every now and then we note in the press some reference to a startling achievement of surgical science. We read of rejuvenation by surgical operation, or even of revival of the dead. What is there to these startling claims? Have they any basis in fact? The answer must be of the "yes and no" variety. Let us see.

The human body does not wear out all at once, cease to function, and collapse. Certain vital parts may cease to function; the other parts may still be quite capable of carrying on their duties. Suppose, for example, the heart stops beating. We are really no more dead from this than we would be if an arm suddenly became paralyzed. It is not because the heart stops that we die, but because it causes death of the other organs by its failure to function. The paralyzed arm would not have done this. If the heart-beat can be stimulated again before death of the other organs actually occurs, then they willingly continue to function. This can often be brought about in an otherwise dead person by the injection of a heart stimulant. Adrenalin is often used for this purpose. Not many years ago such a person would have been pronounced dead; now, if the heart can be stimulated to action and the

cause of its stopping removed, he may live again for many years.

Likewise surgery now offers the possibility of the substitution of a more reliable heart. This does not appear to be possible by the substitution of an animal heart for a human—a process which was at one time much before the public eye as a possible rejuvenation method, but which has failed. The blood at once sets up a reaction against the introduction of foreign cells, even when they come from the same species. The result is that while they function for a short time they soon sicken and die. It would appear that if we are to make substitutions they must be like the larynx referred to above, not mere transfers of an organ of one body into another; artificial organs must be used. As a matter of fact, artificial hearts have been made and have functioned successfully over long periods of time. Dr. O. S. Gibbs, of Dalhousie University, has been able to place rubber hearts in cats by surgical operation. These hearts are in the nature of rubber pumps, and their sole function is to keep the blood in motion, apparently all that is necessary for a heart to do.

Whether or not such hearts shall ever be used in human beings to replace defective ones is a matter of speculation outside the field of this book. It would appear, however, that an in dividual afflicted with heart trouble and know-

ing that his heart may cease to function at any moment might be willing to use such a device to prolong his years.

Interesting experimental work has been done in the revival of such organs as the kidney, liver, heart, and even the brain, after removal from the body by operation, all of which may eventually contribute immeasurably to the possibilities of surgery. Chief among the workers in this fascinating field are Professor Feodor Andrievitch Andrieve, a Russian scientist, and his assistant, Dr. S. S. Brunkhanenko. The latter has actually been able to keep alive the head of a dog severed from the animal and supplied with artificial blood from an artificial heart. For three hours the head of the dog is reported to have had every indication of life. It swallowed cheese, rejected acids, and moved its eyes. This is no more surprizing than the jerk of a severed frog's leg when touched by a high voltage wire. The nerves are still capable of reaction even tho the rest of the animal is dead.

But just what does this mean to the surgeon? It does not mean, of course, that he can completely disassemble a patient and leave the parts lying around until he gets ready to put them together again, as a garage mechanic would treat an automobile. It does, however, offer the possibility of substitution of parts, just as a voice-box may be substituted for a larnyx, as a man's

skull may be replaced by a platinum one, and so on. It also offers the eventual possibility that parts may be temporarily removed for close observation. Surgery is in an interesting state of development.

Ultra-Violet Light

Probably there has been no more important development in medicine of recent years than the introduction, study, and use of the ultra-violet. No sooner were its beneficial effects in the case of rickets discovered than its effects on the system in general were determined, the results of eating food radiated with this ray investigated, and finally the exact chemical substance in the food responsible for this effect isolated. Ultra-violet has become a fad almost overnight.

There are those who question the advisability of the use of an unknown tool of this sort to such a wide extent without its having been tested by time. They point out the ill effects which attended the early use of the x-ray by physicians who had no knowledge of its dangers. On the other hand, we are reminded that there is nothing in the ultra-violet light which is not present to some degree in ordinary sunlight. This cannot be said of the x-ray. But why, they ask, take healthy individuals and subject them to a ray the intensity of which has not previ-

ously been applied to man? The fact is that while the intensity is large it is never used over long periods of time. The likelihood is that man, in his primitive state, was subjected to much greater exposures. With our artificial modes of life, our clothes, our buildings, and our smoky cities, this health source has, for most of us, been largely cut off. We must take our supply in short, intense doses. When not taken in excess, it is the general opinion of the medical profession that these treatments are decidedly beneficial.

To quote the eminent English authority, Professor Leonard Hill, M. B., F. R. S.: "Mist, smoke, pollution, glass windows, walls and roofs and clothes cut out the sunlight and deprive us of the effect which the sun naturally exerts on naked wild men and animals—for example, on ergosterol, which, eaten in the food, is present in the skin, and there awaits activation into vitamin D by sunlight." After pointing out the value of these rays in the prevention of rickets, along with which goes decay of teeth, liability to catarrhal and low infections, and so on, he further sums up the value of actinotherapy as follows:

"The damage of the living cells in the skin produced by sunburn provokes secondarily a local hyperemia, œdema and leucocytosis, followed by desquamation and pigmentation. The

inflammatory reaction increases the power of the blood to kill staphylococci as tested in vitro. In some way, as yet unexplained, it provokes a better feeling of health and vigor, but overdosage may have the opposite effect. The inflammatory reaction helps the skin to recover from infections such as lupus. This terrible disease is cured by local and general light baths. Surgical tuberculosis is benefited by light and open air."

But it is no longer necessary to eat food containing ergosterol and wait for its activation into vitamin D by sunlight. The food itself, or even the extracted ergosterol, can be activated directly by ultra-violet light and then taken into the system. This material is so potent that a mere speck ot it taken each day is sufficient to prevent rickets. A speck is as potent as a few pounds of cod-liver oil. Irradiated foods, sunshine pills, and so on, are becoming the vogue, and there appears to be little if any evidence that the effect on the system is anything but beneficial.

VII

MAKING MAN TO ORDER

The Riddle of Heredity

"THERE'S a divinity that shapes our ends, rough-hew them how we will," states only part of the truth. There is certainly a power which is mostly responsible for shaping our ends, but which nevertheless can be somewhat influenced by the rough-hewing process. This is the equivalent of saying that we are subject to two forces—heredity and environment. A knowledge of the manner and degree in which both of these factors are operative is of the utmost importance to man.

Let us first consider heredity and see with what facts science has been able to present us. Heredity follows a single great law, upon which all our knowledge of the subject is based. This law, known as the Mendelian Law, was discovered by an Austrian monk, Gregor Johann Mendel, in 1865, as the result of his observations on sweet peas. It is applicable to all animal and plant life. It is interesting to note that, published in an obscure journal, it lay buried, unknown by the world's scientists, until 1900. During that interval they were largely groping in the dark.

This law recognizes in each individual's make-up both dominant and recessive characteristics; the color black, for instance, is dominant over red in Aberdeen Angus cattle. The law can best be described by an example. Let us assume that two people mate, the one having blue eyes and the other brown; the brown eyes being a dominant factor and the blue eyes recessive. Then, according to the Mendelian law, the offspring will have brown eyes, the dominant characteristic. At the same time, however, this person will possess the ability to transmit either of these characteristics to his or her offspring. It will be found that three-quarters of the offspring of this second generation will have the dominant characteristic, brown eyes, and the remaining quarter will have blue eyes.

Now, what may we expect to find in the offspring of the third generation? If two of these members, showing the recessive characteristic, are bred together, the subsequent generations will carry this hereditary factor, blue eyes, constantly. If those members of this generation which show the dominant characteristic are observed, it will be found that one-third of them produce purely dominant offspring, while the remaining two-thirds will go on producing the same proportion of recessive, pure dominant, and hybrids that were produced by the third generation.

Thus, if we know the dominant from the recessive characteristics, we can predict the results of any mating. We know that the offspring of the first generation will have only the dominant characteristics. We know that the second generation will be three-quarters dominant and one-quarter recessive. We know that the next generation will be divided so that one-third of them are capable of transmitting the recessive characteristic only, that one-third of the remainder will be capable of transmitting the dominant factor only, and that the remainder will have the same powers as had their parents; their offspring will be divided just as was the parents' offspring. The importance of the knowledge of this law to humanity can hardly be overestimated. It is essential to any intelligent approach to a solution of the riddle of heredity. The study of heredity is reduced to a scientific basis.

Blue-Prints for the Next Generation

But science has gone farther than this. It has been satisfied with nothing less than knowing how these heredity factors are transmitted. It has gone into the germ cells themselves and has discovered exactly what it is in these cells which is responsible for hereditary transmission. In all plant and animal life it has been found that the reproduction cells contain a number of small microscopic rod-like bodies. These are called

chromosomes. The number of these chromosomes in any particular cell depends upon the plant or animal to which it belongs. In general it can be stated that for any particular species the number is always the same, but to this there are many exceptions. In some cases the number is quite variable. In man the number of chromosomes *is always twenty-four.*

When a mating takes place, each of the fertilized cells will again contain twenty-four chromosomes. Half of these will have been contributed by the male and half by the female. Thus it is not possible that the offspring may partake wholly or in major part of the characteristics of the one or the other of its parents. It must partake of the characteristics of each. Nor should it be imagined, if this is true, that brothers should have characteristics necessarily alike. There are an enormous number of ways in which chance might select twelve each out of two groups of twenty-four things. That two brothers should be born of selections of the same identical chromosomes from each parent is possible, but they would so closely resemble each other as to make it difficult if not impossible to distinguish the one from the other. This is the case of identical or one-egg twins. Such twins are the result of the splitting of an egg after fertilization, and the individuals should therefore have the same group of chromosomes. That they are as like as

two machines made in a factory from the same blue-prints is evident to any one who has known such individuals before the factor of environment has entered in to affect the one or the other noticeably.

Some striking work in this field has been done by Dr. Arthur M. Banta, of the Carnegie Institution of Washington. He has made an exhaustive study of water fleas. These animals, like a few other forms of life, have the ability to produce young without the necessity of the egg being fertilized by the male. Dr. Banta has studied nearly nine hundred generations of these fleas, all produced from their parents without egg fertilization. Each generation can have only the same set of chromosomes. In all this time no new chromosomes have been introduced. The last member of this long line of descent has the same kind of chromosomes as the first. Throughout, each member of this family has been as much like all the others as identical twins, daughter like mother, grandmother, great-grandmother, and so on.

But an individual has more characteristics than can be represented by twenty-four chromosomes. It is obvious that these bodies must each have wrapped up in it the possibility of transmitting, in whole, a large number of characteristics. Each factor contained in the chromosome is called a gene and is thought to consist of a

bundle of atoms or molecules. With each gene some particular trait is identified, but to the present time it has been found next to impossible to associate particular traits definitely with particular genes. In a few cases of plants, where chromosomes with similar ends have been found in two varieties, identification or rather localization of the gene has been possible. In this case the fact that both varieties possess one gene in common makes it probable that the characteristic associated with that gene should occur twice as often. This can, of course, be observed.

When it is possible to associate these characteristics with particular parts of the chromosomes, the possibility of making an individual to order is evident. To do such a thing in practise, however, is far outside the probable. Certainly in the higher forms of life it is impossible to imagine that it can ever be done.

Speeding Up Evolution

But certain and definite tho the foregoing exposition of the process of heredity may seem, it is, in fact, far from it. Nature has a way of occasionally completely fooling us, leaving us quite baffled. Every once in a while, not often, something goes wrong; an entirely new and previously unknown trait is introduced. There may be no trace of criminal traits in the entire family tree of either parent, and yet a criminal

is produced. Perhaps, in the other direction, those of a low degree of intelligence may produce a genius. In Dr. Banta's water fleas, with no opportunity of a change in a chromosome pattern, there was suddenly produced an individual with a different shaped head which persisted in the succeeding generations. When such a thing happens under observation it is of the utmost importance to science. We are witnessing evolution at work. Such a change is called a mutation.

When a mutation occurs it may be for the good or the harm of the race. It may produce an individual more or less adaptable to its environment. In the latter case the individuals are better able to cope with hardships than are the other members of the race, and this group will persist while their less fortunate brothers will perish. For one useful mutation it is probable that a hundred or more useless ones will likewise have taken place.

Just what causes these mutations is still a decided mystery. We can only guess. Evidence, which directs our guess somewhat, suggests that it must be due to some rearrangement of the molecules or of the atoms, or even a change in the internal structure of the atoms themselves. This latter suggestion seems at present to be the most likely of the three. It is based upon

the recent work of scientists in which they have been able to produce mutations at will.

This exceptional feat has been found possible by irradiation of the sex cells of both plants and animals with either x-rays or radium. In this way animals or plants can be produced at will which possess characteristics wholly different—different in a marked degree—from those of either parent. In this way evolution can be speeded up. But one should not anticipate that we can in great measure improve animal life at will and immediately. As has already been said, but few mutations are useful mutations. In general the method may be said to produce monsters.

That the mutations produced in this way are due to a change in the internal structure of the *atoms themselves we have grounds for believing.* In the study of the structure of matter by physicists the x-ray is used for the very purpose of altering the atomic structure; and it never fails. If the biologist is ever to study the modification of cells by this method with anything like the detail that physicists have used, he is up against a much more difficult problem. He has the ever-present difficulty of avoiding killing the cell, an obstacle to exact measurement which the physicist does not encounter.

Effect of Environment

Whether heredity or environment is the stronger factor has often been debated. Both are of great importance. In thinking of environment we must, of course, think of it as operating over a long period of time, for generations. In this case its significance is obvious.

Dr. Arthur M. Banta has studied this factor in water fleas under various conditions. These insects, under favorable summer conditions, produce only female offspring. In the fall, however, when the waters of the ponds recede and food becomes scarce, males are produced. Experimenting in the laboratory, he has found that the proportion of males to females can be varied at will by controlling the conditions. He has found that such factors as crowding, food shortage, and so on, have the effect of producing males. The fertilized eggs are hardier and more capable of withstanding adverse conditions and consequently are to be preferred for the perpetuation of the race. Cold, drugs, anything that tends to reduce the metabolism of the female, will produce a predominance of male offspring.

The relation between environment and heredity is clearly shown in goitrous families. The susceptibility to this disease is a heredity factor, but the disease will not be brought out except by factors of environment. It will be brought

out by a deficiency of iodine in the diet. Goitrous families living in the Great Lakes Region, where the water does not contain iodine, have always suffered from this disease. It was not until this cause was determined that much could be done for them. Now the disease can be prevented by supplying the missing environmental factor in other ways. It is frequently added to the diet in the form of iodized salt.

A certain kind of idiocy, known as cretinism, is likewise an environmental problem. It has been found to be due to inactivity of one of the glands, the thyroid. Feeding a cretinous child the extract from the thyroid gland of an ox has been known to restore it to a normal condition. This single environmental factor is extremely important. No less so is any factor affecting another gland, the pituitary. The pituitary gland, situated at the base of the brain, produces the hormone, a chemical substance, which is responsible for the development of an animal to maturity. Taking this hormone from mature rats and injecting it into infant rats, they become mature in eight or ten days. Hormones are largely responsible for the growth, development, capacity, and health of the individual.

Dr. John Munroe, of Long Island University, has made extensive tests over a number of years of the effect of food on the mentality of school

children. He has shown conclusively that this is a major factor. He has found that in poor families an increase in the number of children results in a decreasing mental capacity in the younger ones. As family circumstances become more straitened, and the food poorer, the children do not develop mentally. In families of means, he finds, the younger children are as bright as the older. He has also carried on feeding tests with brothers and has been able to obtain definite results in a great number of cases.

You cannot make a fast animal from a plow horse merely by stabling him with thoroughbreds, feeding him the same way, and in general giving him the same treatment. He will never equal the pace set by his stable companions. He will probably become, however, much faster than other plow horses.

Control of Sex

Can we control sex? That is always a question that parents wish answered. They would like to know that a boy or a girl, as the case may be, could be assured to them. Unfortunately for their hopes, science cannot as yet give them any comfort. Sex can be controlled, or even transformed, in some animals and birds, but in man —not yet.

The sex of the individual that will be born

of a particular egg fertilization depends either upon the kind of egg fertilized or upon the kind of sperm cell which fertilizes it. In some cases there are two kinds of eggs and one kind of sperm cell, as in some birds; or as in the case of man, there may be two kinds of sperm cell and but one kind of egg. When thousands of each kind of sperm cell are produced at each union of male and female, it is obvious that whether a male or female is produced is entirely a matter of chance. The only hope of sex control here would be in the possibility of separating out the particular sperm cell to do the fertilizing. Such a chance is very remote.

In the case of frogs and birds, which produce their eggs in a convenient form for experimentation, much has been done. It has been found that an egg which would produce a female frog if developed can be made to produce a male frog by making it undergo early development at high temperatures. If low temperatures are used the reverse will be the case. Males may also be produced by allowing the eggs to become overripe before fertilization.

In pigeons it is possible to produce only males by suitable mating. If two entirely different species of pigeon are mated, only males will be produced. This, in the human race, would correspond to mating a human with an animal as

different from it as the gorilla. It is not a likely or desirable method, so far as humanity is concerned. Yet, while in general it is not possible to predetermine the sex of a bird, it is often possible to change the sex after the animal has been born. Female chickens have always a good left ovary and a minute and disappearing right ovary. Now, it has been found that if the good ovary on the left is removed, the right ovary begins to develop. But it develops in a remarkable and unexpected way. It turns around and becomes, not an ovary, but a testis. The whole sexual apparatus then develops into the male system, and the bird, formerly a female, becomes a male and functions in its adult stage as a male. Other methods of accomplishing this apparent miracle are also known.

It has been observed that whatever tends to produce males is accompanied by an increase in the metabolic rate, and whatever tends to produce females by a decrease in this rate. This has led to the metabolic theory of sex; the suggestion that the rate at which the life process goes on is the sex determiner. According to this theory sex might be ultimately controlled by controlling this one factor. And here we seem to have the most hopeful of the methods which might eventually prove applicable to human beings. It would appear that control of metabolism might be affected by such things as temperature,

air supply, and so on. Thus it may be possible, in some measure, to control sex.

That there are at the present time border cases amongst humans is well known to all. These unfortunate individuals do not have their sex definitely determined. Many would welcome any treatment which might in any way tend to fix their sex characteristics. Biologists working on this problem constantly receive communications from these unfortunates. Perhaps some day their problems may be met, but at present it cannot be said that such a consummation is in sight.

VIII

THE STRUCTURE OF MATTER

Molecules and Atoms

UNDOUBTEDLY one of the hardest nuts to crack, for the beginner in modern physics, is the true conception of the molecular structure of matter. It is difficult to conceive the enormous number of minute molecules in even the smallest obtainable particle that the eye can see, even under a powerful microscope, and to imagine the velocities with which these particles are constantly moving about and hurtling against each other. The idea is not a new one. It is as old as civilization. Certainly the early Greeks had formulated a theory of matter similar to this. Democritus and his school, in fact, expressed the modern theory almost exactly as we know it to-day. Then, however, all was mere speculation. Science was a philosophy and was subjected neither to experimental test nor to the keen mathematical analysis that we know in this age. He who said that matter was continuous, therefore, had an equal right to be heard. We can now be certain that matter is discontinuous; that the distance between particles is in general many times the diameter of the particles themselves. To see them with the eye shall ever be denied us. No

instrument we may ever expect to develop will avail us anything. We are limited by the nature of the eye itself. But there are other kinds of evidence more reliable than sight which give us our knowledge—evidence which is quite unimpeachable. Thus we know that while a board, a bit of steel, or some liquid does not present visible holes, they are there, nevertheless. There is far more hole than board, or steel, or liquid. At a distance a forest appears to be a solid mass of leaves. On close approach the leaves are found to be quite far apart. The same would be true of any material if we could reduce ourselves to a corresponding dimension and at the same time have our eyesight suitably modified.

Stranger even than the granular theory of matter, is the fact that the individual particles are moving about with great velocity. Because of the numerous bumps with other particles, they never get very far. Accordingly the motion can best be described as a shivering. Hydrogen molecules, which move with the greatest velocity of all because of their lightness, actually travel at the enormous speed of about a mile a second under normal conditions of temperature and pressure. Two other familiar gases, oxygen and nitrogen, being heavier than hydrogen, travel at about one-fourth that rate.

If we were to examine a few molecules of various materials picked up at random, we

should find that they in turn were subdivided. They might have two, three, four or almost any number of parts. These pieces, next in size to the molecule itself, are called atoms. Modern science assures us that there are in all but ninety-two of these atoms, or there are but ninety-two elements. Of various combinations of these all our familiar materials are composed. These are the tools of the chemist. It is with them that he has his chief concern. Up almost to the beginning of the present century, atoms were supposed to be the smallest particles of matter, and indivisible.

Take, for example, a particle of common salt. If we examine one of its molecules, we find that it is made up of two atoms. One of these will be found to be an atom of the element chlorine, which by itself would be an ill-smelling greenish-yellow gas heavier than air. The other atom, sodium, is a metal, which, if placed upon water, burns with a great sputtering. No one would for a moment dream of inhaling the gas nor of eating the metal. Yet combined as salt they are palatable enough. It is worthy of note that these atoms know just how they wish to combine. If a chemist uses more sodium than is necessary for a one-to-one combination of atoms, there will be just that amount left over after the chemical reaction has taken place. In other

cases a two-to-one combination is needed, or a three- or four-to-one.

Man Probes the Atom

The discovery of the x-ray did many other things than make it possible to mend broken bones or dig bullets out of doughboys. It gave us a new tool with which to probe inside the atom. It was early observed that the air in the neighborhood of an x-ray tube became electrically charged. This was at first decidedly baffling. Did the x-ray shoot out charged particles? Or did it in some inexplicable manner break the particles of air up into charged pieces? The latter proved to be the case.

At once scientists set out to investigate the nature of these charged fragments of air atoms. Foremost among them was Sir J. J. Thomson, the brilliant English physicist. He found that these particles when set in motion could be easily deflected by means of either a magnetic or an electric field. They behaved in a manner somewhat similar to that of a wire carrying an electric current. By measuring the deflections and the fields causing them, together with the voltage used to set them in motion, he arrived at the velocity with which they were made to move. It was comparable to the velocity of light. Even the slow ones moved at as much as 18,000 miles a second. Similar particles which were

obtained from radium actually reached velocities as high as 160,000 miles a second. These were the so-called electrons, or beta particles, as they are called when radioactive materials are the source. Further experiments led to a knowledge of the ratio of their charge to their mass. It remained for R. A. Millikan to measure these separately at a later date.

The measurement of charge to mass at different velocities led to a somewhat startling result. It was found that the mass was not constant, but increased as the velocity increased, and it was not until the relativity theory came to the rescuc that this result was understood.

In addition to the electrons, which were at once identified and measured as described, there was also found to exist another type of particle. These latter particles were at first referred to as canalstrahlen, because first found streaming through a fine hole in a metal part of one of the tubes used to study the electrons. At first these streams of particles defied all efforts to bend them by means of electric and magnetic fields. They were accordingly thought to be similar to light rays, and so quite diffcrent in nature from the electrons. Stronger fields succeeded, however, and the streaming specks were identified as positively charged particles, oppositely charged to the negative electrons. The initial failure to turn them in their path had been due to their enor-

mous mass as compared to the electrons. They were found to be about 1,800 times as heavy—equal to the mass of a hydrogen atom.

A notable advance in the study of these newly discovered particles was made when C. T. R. Wilson, then a student with Sir J. J. Thomson, found that their path could be rendered visible by shooting them through water vapor on the point of condensing. The droplets had a decided tendency to condense on the charged particles of air left in the trail of the speeding electrons. This same fact of condensation also offered a means of measuring the charge of electricity on a single electron. By putting a suitable charge on a plate held over the water the droplets could be made to remain suspended. The method, consequently, has sometimes been called the Mohammed's coffin method.

Because of the multiplicity of drops of a variety of sizes it was quite impossible to make the measurement with any degree of accuracy. It was at this point that Prof. Millikan took up the study with results that are more or less familiar to every one. He devised a method that had all the advantages of that of Wilson, but that enabled him to deal with a single drop at a time. For his purpose he found an oil droplet the most suitable. He was able to observe the fall of such a drop under the action of gravity, and its rise, due to the application of an elec-

tric field on the plates between which the drop was suspended. Sometimes a single drop was kept under observation for as much as six hours, and the variations in time of rise as it gained or lost electrons was carefully measured. In this way he was able to measure the charge on an electron with great accuracy, and in fact to prove for the first time that such a thing as an electron really existed. Up to that time it had been thought possible that the ratio of charge to mass remained constant while both varied. No longer could any such thought be entertained. Millikan paved the way for our modern electrical theory.

Only Two Types of Building Blocks Compose All Matter

The next great step forward was taken by a young man in his twenties—Moseley. Moseley was killed in the early days of the war at the age of twenty-six, not long after his epoch-making discovery. It has been frequently said that Moseley's death was one of the greatest losses suffered during the war. He had succeeded in showing conclusively that all atoms were made up of but two building blocks, positive and negative particles, electrons and protons. He had fulfilled an old, old dream of all physicists and chemists—that of reducing all substances to mere differences in architecture. Thus

our ninety-two elements became but different arrangements of two kinds of electrified particles. Iron differs from the air we breathe only in the number and arrangement of these particles; air differs from water, or from gold, or from platinum only in this one respect. The significance of such a contribution needs no elaboration. Moseley has left a great monument to himself that will endure as long as civilization itself.

One may well demand to know how such an achievement was brought about. The answer is, through the agency of the x-ray. Moseley used the x-ray spectrometer, which was already developed by others, for his purpose. X-rays are producod whenever an electron moving at high speed hits a target. The effect is somewhat analogous to hitting a wall with a ball. The energy of the ball is lost, but in its place sound is produced. In Moseley's work the analogy is more truly expressed by replacing the wall by a carillon, each bell—and we will assume there are ninety-two of them—representing an electron. If a ball hits one of these a sound characteristic of that particular bell is produced. So when an electron hits a particular kind of atom an x-ray characteristic of that particular atom will be produced—provided, of course, the electron had enough energy. The characteristic x-ray wavelengths thus produced follow a scale, very much

as do the notes of a musical instrument. From such data he arranged all the atoms in the order of decreasing x-ray wave-lengths, beginning with hydrogen as one and ending with uranium as ninety-two. This is called the atomic number arrangement. It differs from the order of atomic weights in only a few instances. The atomic number of any element is equal to the number of electrons in the atom outside the nucleus. As these are the binders, the so-called valence electrons, which are responsible for chemical combination, the atomic numbers are of much greater importance to the chemist than are the atomic weights. The exact reasoning whereby Moseley was able to identify his x-ray wave-lengths with a particular arrangement of electrons and protons is much too involved to find a place outside of treatises devoted to such subjects.

Is Light Done Up in Bundles?

Before we can attempt to go into the matter of actual arrangement of the atomic building-blocks, we must retrace some of our steps. We have been talking much too glibly about wave-lengths, when, as a matter of fact, we are far from certain that any such things exist. In the early days of the study of light, two theories existed—the wave theory and the corpuscular theory. One held that light consisted of waves,

the other that it was made up of small particles. The latter view was supported by no less a person than Newton. Developments for a time completely discredited the corpuscular theory. Any early twentieth century physicist would have told you unhesitatingly that light was a pure wave phenomenon. But about this time, when all was smug, scientists began to inquire too closely into the distribution of energy from a perfect radiating body. Such a body, usually referred to as a *black* body, does not give off an equal amount of energy in the various wave-lengths, but follows a mound-shaped distribution curve. Attempts to explain this on the classical theories turned out to be futile.

At this point Planck introduced the quantum theory. According to this hypothesis, all radiant energy consists of bundles of energy called quanta, the size of which corresponds inversely to what was formerly called the wave-lengths. Confusing tho it may be, it seems impossible completely to divorce the idea of waves even from the quantum, and we are inclined to think, despite its apparent inconsistency, of a quantum as having a wave associated with it. Fortunately for our peace of mind, modern experiment is tending to show that this position is, after all, justified. We are beginning to see that this fundamental speck of energy has properties of both wave and particle. Stranger still, we now

have evidence that the electron, long regarded strictly as a particle, has also wave characteristics. This may yet lead us to the conclusion that the fundamental unit of energy, the fundamental speck of matter, and the fundamental unit of electricity are all one and the same thing.

The quantum theory, while devised to account for the shape of the radiation curve, at once proved useful in the study of the structure of the atom. Whenever a material is excited to radiation, as by heating to incandescence in the case of a solid or by exciting with an electrical discharge in the case of a gas, it gives off light characteristic of itself. When this light is split up into its component colors it forms what is known as the spectrum of the substance. It is the thumb-print of that particular material. Nothing else will have the same spectrum.

Each of the colors in the spectrum is referred to as a line, for they exhibit themselves merely as lines in the ordinary photograph of the spectrum. Study of these lines in the simpler elements—hydrogen, for example—has shown that they follow a definite plan; that the wave-lengths can be fitted into a mathematical formula, which, by the substitution of the proper constants, will give the wave-lengths of each of the lines which the substance is capable of producing.

It is not a far step to imagine that these lines

or colors must in some way be connected with the arrangement of the parts of the atom, but just how is not so easy to determine. Many scientists have attempted to correlate these lines with atomic structure, but at present none of these theories is accepted as final. Until recently, the generally accepted theory was that of Bohr. Certain shortcomings were of course recognized, but it was more or less expected that further research would clear up some of the mystery. Instead, further research has tended to make the theory more and more untenable. The discovery which has associated a wave form with the electron has been the most damaging to the Bohr theory, and has pointed most favorably to a more recent theory based on what is called wave mechanics.

Atomic Architecture

The Bohr theory, still extremely useful for an understanding of modern physics, is, briefly, somewhat as follows: Each atom is considered to be what in some respects corresponds to a miniature solar system. There is a central positive nucleus which corresponds to our sun. Around this revolve the electrons. The nucleus is a massive affair. It is here that all the measurable mass of the atom is to be found. It consists, in the case of hydrogen, of a single proton. In all other atoms it consists of several positive

particles bound together by electrons. Thus helium, the next simplest atom to hydrogen, has four positive and two negative particles in the nucleus. The electrons outside of this nucleus revolve on orbits which are elliptical, being but slightly off circular paths. For a particular kind of atom these orbits are very definitely determined. There are a limited number of possible orbits. If for any reason an electron leaves one of these orbits it will reappear on another. There is no possibility that it may revolve midway between two of these preferred orbits. Just why these orbits are so definitely fixed has always worried the proponents of this theory. We cannot say why this is so. We can only say that all the evidence points to it as a fact. If it were not so we should never have definite spectra associated with different substances. Each substance, when rendered luminous, would produce a continuous band from one end of the spectrum to the other, if indeed it produced any at all.

This, of course, suggests a question. How is radiation produced by an atom? Our theory tells us that radiation is given off from an atom every time an electron leaves its orbit for one nearer the nucleus. When it does this it loses some of its energy, and it is this energy which is thought to produce the radiation. Thinking back to the quantum theory, we have an explanation for this. This sudden loss of energy

gives us the amount of energy bound up as a quantum. Thus the size of the quanta given off from the atom depends upon the architecture of the atom, and as no two elements have the same configuration no two will produce the same spectrum. By their quanta you shall know them.

Where is the electron while it is going from one orbit, or energy level, to another? And just how does it bundle up the energy and send it out always with the speed of light, 186,000 miles a second? Few have attempted to hazard a guess, and their guesses are of little value. We have quite insufficient data to make speculation at all justifiable.

The more modern wave theory of the atom is almost purely mathematical. It is difficult to draw a physical picture of the atom based on it. Perhaps on this theory the atom can best be described as a series of nebulous charged shells surrounding the nucleus, the density of each shell fading off in each direction along its radius.

Transmutation of the Elements

One cannot leave the subject of atomic structure without a consideration of radioactivity. Here we find a mass of heavy, complicated atoms, such as uranium, gradually disintegrating, becoming one substance after another, until it finally becomes lead. It is natural transmutation. This occurs through a natural expulsion of posi-

tive particles from the nucleus in the form of a so-called alpha particle (which is nothing more than a helium atom minus two of its electrons), or through the expulsion of an electron from the nucleus, the electron in the latter case being called a beta particle because it was not at first identified.

As the material is changed from one substance into another, one of the interesting things is the length of life of the different forms. Only one-half of some substances is transmuted over a period of millions of years. Other substances are changed completely in a few seconds. Radium has a half-life period of about 1,700 years. At the end of 1,700 years half of whatever you had at the beginning of that time will be gone. A radium atom endowed with human intelligence would never believe such a disintegration possible. While we, with millions of atoms in the tiniest speck we can obtain, always find many particles being thrown off, from the atom's point of view it might live for centuries with never one of its neighbors exploding. The atom would believe it as improbable as we would believe a miracle which only one man had seen and whose veracity was far from noteworthy.

One may justifiably wonder how it is possible to determine the half-life period of a substance which lasts for centuries. No one has lived long enough to measure it, and in any case radio-

activity was only discovered at the close of the last century. It is done by counting the number of particles which are given off in any one of several ways: by observing the flashes as they strike a fluorescent screen, by computing the number from the heat effect, or by noting the change in current produced in an ionization chamber. With these data and a knowledge of the total number of atoms present, known from the usual chemical data, one can determine the rate of disintegration and hence the time required for half the material to be used up.

If we have transmutation taking place in the radioactive elements despite any attempt that we are capable of making to stop it, is it not possible, then, to produce transmutation in the lighter elements if we give them some assistance? This can be done.

Rutherford, by bombarding nitrogen with alpha particles from radium, was able to produce hydrogen and helium. Further research proved that the same could be done with several of the light elements. In the case of the intermediate atoms, however, nothing has been done. Thus far it seems hopeless to try to transmute these elements. This is unfortunate, for the group of intermediate substances includes the metals which it has always been man's desire to transmute. It would be of great advantage to us

if we could transmute these, but our only hope now is that our theory may be wrong.

A Ton of Radium

Some time ago one of the products of radioactive disintegration was produced artificially. Lenard succeeded in getting electrons, produced by a high voltage in a vacuum, out into the air. He shot them through a thin metal window. Recently Dr. W. D. Coolidge, by using higher voltages and thinner windows, has succeeded in getting a copious supply of these electrons out into the air. He used voltages as high as 900,000 volts. It is estimated that if he could build a tube to operate on 3,000,000 volts it would be equivalent to a ton of radium. As voltages as high as 5,000,000 volts are now available, it remains only to construct a tube capable of withstanding this high potential difference. Doubtless it will eventually be accomplished. When it is, we shall have at our command a powerful medicinal tool whose uses can at present be no more than vaguely guessed.

The whole theory of the structure of matter is in a decided state of flux. Theories of to-day suggest experiments to be tried to-morrow. They in turn suggest modifications of the theory, which may lead to a wholly new line of thought and to another theory hardly capable of identification with the first. Thus modern science

moves on, always changing, always advancing to new truths. There is a danger that before this is in print it may be altered in some respects by new discoveries. The present sketch will serve, however, to give a reasonable picture of twentieth century physics.

What Is Light?

The subject of radiation is rather comprehensive. It includes in its scope all ether-wave phenomena, beginning with radio waves on the one hand and ending with the minute cosmic waves on the other. Between these limits come the infra-red, our principal heat-bearing waves (sometimes called heat waves), the visible light to which our eyes are sensitive, the ultra-violet so much in the public mind recently because of its therapeutic value, and finally x-rays and the gamma rays from radium. These range all the way from wave-lengths of thousands of meters down to those so short as to be of sub-atomic dimensions. It is, of course, impossible to put definite limits on these; to say where one begins and the other leaves off. We frequently call the same waves infra-red or electromagnetic (radio), depending on the method of detection. If it is a method common to the radio field, we call the waves electromagnetic. If it is one usually employed in making measurements in the infra-red, we call them infra-red waves. Were it not for

the various manifestations which are peculiar to certain wave-length regions, and the discovery and measurement of these independently, all the waves we are talking about should have been called by the same name, probably electromagnetic waves, as they all actually are. There is no difference from one end of the spectrum to the other except in wave-lengths.

We have already had some discussion concerning the relative merits of the quantum theory as opposed to the wave theory. In general the former may be said more nearly to fit the facts for short-wave-length phenomena and the latter for long-wave-length phenomena. Thus x-rays and the ultra-violet lend themselves to explanation on the quantum theory, while radio phenomena are almost always described in terms of waves.

Perhaps the outstanding argument in favor of the quantum theory is the photoelectric effect. When radiation strikes a metal, particularly one of the rare earth metals, such as sodium or potassium, it frees electrons from the metal. The astonishing thing about these electrons is that the speed with which they leave the metal is entirely independent of the intensity of the light which falls on the metal. It may be a candle a foot away or a mile away: the electrons are driven off with the same speed. Only the number of electrons given off differs with distance

from the light. The nearer the light, the more electrons. This we would expect. But if we try to account for this phenomenon by the wave theory, we run into considerable difficulty. The electron speed is found to depend wholly upon the wave-length. The shorter the wave, the greater the velocity with which the electrons come off. It would appear on the wave theory that the electron was only shot off when it had stored up the necessary amount of energy. But if we assume that the light is equally spread out over the metal surface and consider the energy which the emitted electron has, we shall find that it would require a wholly absurd length of time for an electron to acquire the necessary energy to be shot off; yet the instant the light strikes the metal the electrons begin to leave. We might account for this by assuming that these first electrons were almost loaded to capacity before the light was turned on; that they had acquired this from previous exposures. We might assume that our light was only required to pull the trigger, as it were. There is nothing, however, in any of our theories of the atom to give us any comfort in this assumption. In addition, to keep up the supply we should have to have about all the energy which falls upon the exposed metal surface collected in these expelled electrons. All would have to collect energy and hand it over to these few. If we are to think of the

release of energy as due to the light pulling some kind of a trigger and dumping the whole load, we are also at a loss to explain why the load dumped depends upon who pulls the trigger. The distanee a bullet travels does not depend upon who sets off the gun, yet this is the case here. Any effort to explain the photoelectric effect on the wave theory proves futile.

Now, on the other hand, let us eonsider the interference of light. A beam of light may be split into two beams, which may be brought back together again in such a manner as to produce darkness. This, on the wave theory, is brought about by having them meet in such a way that they are a half wave-length apart. To use a water-wave analogy, they are recombined in such a way that a erest of one wave strikes a trough of another. Thus the "upness" of one wave is combined with the "downness" of another, and a zero motion results. Try to explain this on the quantum theory! It requires that you think of two bundles of energy coming together and annihilating eaeh other. We might be able to get around this in some manner if it always happened. But it happens only when they are eombined after traveling distanees that are differcnt by definite amounts. It is difficult to eoneeive of a quantum that has its characteristies altered so markedly by sueh slight path differenee as is represented by a half wave-length. Any attempt

to explain interference on the quantum theory can only prove ridiculous.

These two phenomena, the photoelectric effect and interference, are but two outstanding cases where attempts to explain them are confined sharply to the one or the other of the theories. There are many others. Unfortunately, at present we can do nothing about it. We must have more experimental data. With this we may ultimately hope to reconcile these two viewpoints of radiation. At present we can only say that each undoubtedly represents a great deal of truth, but that neither represents the whole truth.

Mass of Electron Increases with Speed

One of the most interesting measurements in the field of radiation is the measurement of the speed of light. Since the beginning of experimental physics there have been many attempts to make this determination. It has been found to be about 186,000 miles a second in air, and differs, of course, with the medium through which it is passing. It is the same in interstellar space as it is on the earth.

Now, in order that a wave should travel there must of necessity be something for it to travel in. Since interstellar space is apparently quite devoid of anything that resembles a medium of material such as we are familiar with, and since

light travels apparently with undiminished energy through distances of thousands of light-years, we have been forced to assume a medium of travel quite different from anything with which we are familiar. This medium has been called the ether. It is weightless, colorless, and lacks all the properties which might enable us to detect it, other than its perfect elasticity, which enables it to carry light-waves.

An important question in regard to this ether is its relation to the earth as it travels in its orbit around the sun. Does it behave as if it were rigidly attached to the earth—with no relative motion? Does the earth pass through it as a bundle of wires might pass through the air? Or does the ether drag after the earth as molasses would drag after a slow-moving paddle? Michelson and Morley set out to investigate this near the close of the last century. They found—and their findings have been frequently verified—that there was no relative motion between the earth and the ether. This was done by measuring the velocity of light both in the direction of and at right angles to the direction of the earth's motion. If there were a drag it should have had an effect on the measured velocity of light, much like that which one would find in a boat in going crosswise or along with the current of the stream.

The result obtained by Michelson and Morley is subject to more than one interpretation. It

might be looked upon as favorable to the quantum theory, as quanta require no medium for their propagation. Other considerations make this not the best interpretation, however. We could assume that the ether is rigid with respect to the earth; but if so, other planets and stars certainly must move with respect to it. We are beyond that stage where we feel justified in considering the earth as the most important speck in the universe. But how else can we account for a failure to observe an ether drift? There is another explanation, but at first it sounds more absurd than either of those just suggested. We assume that the measuring instruments used by Michelson and Morley became shortened in the direction of the earth's motion an amount just sufficient to mask the effect of a drift which actually existed! This is known as the Lorentz-Fitzgerald theory of contraction. Experimenters have tried various substances; but if this contraction takes place, the substances all contract the same amount, as the theory would suggest.

This theory of contraction gains support from measurements on the mass of an electron and its variation with speed. It was found that an electron increased its mass with velocity in such a way that at the velocity of light its mass would be infinitely great. Did this mean that all the equations giving our usual dynamical relations would have to be abandoned in the case of the

electron? Was that an exception to all our classical laws? Not if we accept this theory of contraction. For, strangely enough, the order of this contraction is exactly such as to offset the increased mass and so to leave our relations between mass, length, and time unchanged. The theory was consequently accepted.

Another victory for this theory has been that it is quite in accord with the theory of relativity as developed by Einstein.

IX

MAN'S ENEMIES

Millions a Year for Weeds

It must be confessed that farmers have many troubles. Farm pests cause enormous losses annually. Of these pests weeds are among the most annoying. Their depredations are so quiet, however, that they are less noticed than are those of insects and birds, for example. Nevertheless, they are taking their constant and, in many places, increasing toll annually. Many farms now abandoned as unprofitable would show a profit if this source of loss were even partially under control.

The loss due to weeds is represented in many different items. These might be listed as the cost of competing with weeds, the cost of cultivation, the dockage on inferior grain and seeds, the expense of cutting weeds on highways, and miscellaneous losses such as animal poisoning, and so on.

Undoubtedly the greatest loss due to weeds has been found to be the direct competition of weeds with the cultivated plants, the growing of weeds on land prepared and fertilized for useful plant growth. The damage reaches into enormous figures. Some time ago the Indiana Experiment

Station made a survey of these losses for various crops. For corn they found a reduction in yield of ten per cent., due to weeds; for tame hay, 3 to 16 per cent.; potatoes, 6 to 10 per cent; spring grain, 12 to 15 per cent.; and winter grain, 5 to 9 per cent. Using these figures as a basis, Dr. A. L. Stone, of the Wisconsin Department of Agriculture, estimates the annual loss to that State from this cause at $25,604,998. This is a direct loss due to occupation of space by weeds which was intended for useful plants.

If we take the second item of loss, cost of cultivation, we arrive at another large figure on the wrong side of the ledger, which helps to make farm relief a national problem. Few farmers cultivate wholly for the conservation of soil moisture, but are at the same time striving to keep down weed competition. The United States Department of Agriculture estimates that the cost of cultivation is one-sixth of the total cost of crop production. One-half of this item is assigned to weed control. Thus one-twelfth of the cost of production is for weed eradication. In Wisconsin, according to Dr. Stone, this presents an annual bill to the farmers of that State of $13,127,775.

Our next item is that of dockage. Whenever grain or seeds are presented to the dealer, the price is lessened if the product is dirty or contains weed-seed or other foreign matter. With

modern methods of harvesting there is little dirt or chaff likely to be found in the grain. Any foreign matter is almost certain to be nothing other than weed-seed. It is agreed among experts that a conservative estimate for dockage is one per cent. for grain and ten per cent. for clover. On this basis the State of Wisconsin, for which figures are available, loses each year, in lowered selling price, the sum of $5,298,440.

Pulling and cutting the weeds on the farm and along the highways, as required by law in most States, also presents a large figure, even on the most conservative estimate. If one allow but five dollars a year in farm labor for cutting weeds on the farm, and three dollars a year in labor or in taxes for cutting the weeds along highways adjacent to farm lands, the total loss due to weeds becomes, for Wisconsin, according to Dr. Stone, $1,545,152.

If now we lump together all such losses as the poisoning of farm animals, the tainting of dairy products by such plants as wild onion, the nuisance caused by vine-like plants in harvesting, damage to animals due to thorns, burs, etc., we may safely set down the figure $500,000 as the loss due to these various causes. This gives us a grand total of $46,076,365 as the loss due to weeds in a single State.

Naturally such a condition is attracting considerable attention on the part of agricultural

agencies. But it must be admitted that the weed problem is not diminishing noticeably. Our present means of easy communication are adding to the problem. Seeds of noxious weeds are now carried rapidly over considerable distances on the wheels of vehicles. It is a lucky farmer who does not discover one or more new weeds on his farm each season. Here is a problem which will test the ingenuity of our best scientists.

Insect War

The second great problem of our farmers is insect control. This is a problem that in general is much more interesting and consequently receives much more attention than the weed problem. Probably it is because we are inclined to think of the insect as having intelligence and definitely attempting to bring about the ruin of man. The battle between insect and man has long been a favorite topic of the speculative writer. That there is some possibility of this very thing happening cannot be denied. Insects were here on the earth long before the advent of man, and they may remain after he has left. The insect may have much to do with man's going.

If one were to attempt to give but a brief description of all our harmful insects it would fill a large volume. Consequently we must restrict ourselves to a survey of the methods of controlling only a few.

In the West the Mormon cricket must be numbered amongst our worst enemies, and because this insect marches in large orderly armies, and thus appears to be definitely directing an attack on humanity, the methods of fighting it are perhaps the most interesting of all.

The Mormon cricket was so called because of its attack, in 1848, on an early Mormon settlement near where Salt Lake City now stands. The insects descended upon the colony and threatened its extinction. Men, women and children worked until exhausted in an attempt to save something of their crops. Finally a flock of gulls from Salt Lake appeared and did what the farmers had failed to do. Because of this apparently miraculous salvation, a monument was erected to the gulls. Thus first notice of these insects came in a romantic manner, and the romantic has been associated with them ever since.

At a certain stage of development they begin their march straight across country. Why they do this no one knows. They will often leave a perfectly good feeding ground for a comparatively barren country. In their march they travel about three-quarters of a mile per day. They climb over large obstacles in their path, and will even go over a house or barn in preference to going around it. They can climb anything but a smooth hard surface.

One of the best methods of heading off the march is to construct tin fences, a foot or so high, across the path. These are of smooth tin, and inclined slightly. The insects cannot climb this. Often ten or twelve miles of such fence is used. At intervals along the fence excavations are made and lined with tin. The insects trapped in these are sprayed with gasoline and burned. They are then shoveled out to make room for further catches. So great are the quantities caught that some commercial concerns have sought to extract the oil from them for commercial purposes, and to use the insects themselves for poultry and hog feed. Neither of these attempts, however, has thus far proved a success.

In addition to using this warlike method of trenches and metal fences, the insect armies are attacked in the rear by poison-dust guns. Where land formation permits, the guns are mounted on trucks or wagons. Otherwise they may be used on horseback. Smaller ones may be used by men on foot. These guns spray calcium arsenate, which kills the insects, not immediately, but in from thirty to seventy hours. Fortunately, they stop feeding almost at once, however. They are killed by licking the dust off their feet, not by eating the plants on which it is sprayed. Thus do we battle with one of our most spectacular insect enemies.

In the case of the boll-weevil, the use of

airplanes to spray poisons over the affected fields adds again to the warlike appearance of insect-control methods. In the case of this pest we have an excellent argument in favor of diversification of crops, another method of control. Where field after field of cotton is grown without a break, conditions are ideal for the spread of the insects. If the continuity is broken by some crop which the boll-weevil does not attack, it offers a barrier to its spread.

A method of insect destruction now beginning to be used, and occupying considerable attention of the scientists, is that of introducing parasites which prey upon and destroy the insects. Many parasites are being imported for this purpose in the case of the Japanese beetle. Orchard-insect parasites also are being bred in this country and shipped to infested regions. Thus we attempt to make the world safe for mankind.

Get Acquainted with Insects

In insect control, one of the first necessities is to know your insect. It is not enough to know merely that it has arrived and must be fought by some material which you may at the moment happen to have handy. You must plan your attack intelligently. It is essential that you know much about the insect's habits, particularly its

habits of feeding, its life cycle, and its breeding places.

It is useless, for example, to spray with Paris green a plant which is infested with plant-lice or aphids. The poison stays on the outside of the leaf, while the insect feeds on the juices inside the cells, which it gets by puncturing the leaf. The pest is immune to such treatment. On the other hand, such insects as slugs, grasshoppers, caterpillars, and beetles have jaws and actually bite off and consume the leaves. Poisons which coat the outside of the leaf are accordingly useful in these cases. It is not difficult to determine which type of insect is at work. In the first case the leaves wither and die, in the second case parts of the leaves will be eaten away. Insects sometimes fall into neither of these classes and will not eat poisoned leaves. The Mormon cricket is poisoned by getting the insecticide on its feet, which it subsequently takes into the system by licking.

Another thing to be considered is the proper time of application. Knowing the life cycle of the insect, one can predict its appearance and spray beforehand. Again, there are those insects whose appearance can be awaited and sprayed as convenient. One should remember that the rate of reproduction is an important factor here. In the case of aphids, where this rate is ex-

tremely rapid, no time should be lost after the pest has been observed.

The time of day at which the application of the poison is made is likewise of considerable importance in some cases. Poison-bran bait is used for both cutworms and grasshoppers, but for the former it is best applied in the evening, for the latter in the morning. This is because the cutworm feeds at night, while the grasshopper feeds in the early morning. In the case of the chrysanthemum midge, the proper time to fumigate is shortly after midnight. Inconvenient tho such a procedure may be, that is nevertheless the time at which the insect emerges for feeding. The time to get it is when it is susceptible to attack.

Again we are greatly assisted if we know where to look for the insect's breeding place. Here we may be able to attack when it is in a position, or in a stage of development, in which it cannot defend itself. White grubs, cutworms, and wire-worms breed in the sod, which indicates the desirability of soil treatment in their eradication. Other insects have their period of development in weeds which, apart from their own injurious effect, are likewise undesirable from this point of view and should not be allowed to grow.

Plant growers should not fail to make a thorough study of the life and habits of every insect which they are called upon to combat. They

should know just what remedy to apply and how to apply it. Without a knowledge of the insect itself it is difficult to determine the measure of success which the remedy is having. Study of insects should be as much a part of the plant grower's concern as is the study of the soil. It is almost equally important.

Termites Need Parasites to Digest Their Food

Termites, frequently referred to as "white ants," altho they are not in fact ants, constitute an interesting yet dangerous menace. These creatures, of which there are 1,600 known varieties, live in ant-like colonies, have a division of labor among them similar to that of ants, and in general follow somewhat the plan of living of ants. Their life cycle consists of three stages, the egg, the immature form or nymph, and the adult form, which may be divided into classes. There are the workers, the soldiers, and those which exercise the sex functions.

Termites are soft-bodied insects and seclude themselves underground or within wood. The workers, which do the work of excavation within the earth as the colony requires, are blind and avoid the light. They are seldom seen. The sexual individuals are winged, have eyes, and at certain seasons of the year migrate, in what might be called swarms, and establish new colonies.

Contrary to popular opinion, these pests are

native to this country and have long inhabited our forests. Only recently, however, have they attacked the settled regions as a result of the destruction of great forest areas. The thing which makes them such unwelcome visitors is their food habits. They can live on either live or dead wood, and therefore can damage all sorts of wooden structures.

The termites may, in general, be divided into two classes. The subterranean species never come above ground, but confine their attacks to wood which they find in contact with the earth. They usually follow the grain in the wood and honeycomb it. They are particularly dangerous in that there is no evidence visible above the ground of what is going on below.

The non-subterranean termites do not need contact with the moist ground to maintain life, and will attack wood above ground. They do not usually follow the grain of the wood, and their activities are easily detected. It is interesting to note how these insects are able to digest dry wood and to secure nourishment from it. This is possible only if they are acting as hosts to suitable organisms. In the intestines of termites are found fauna and flora of great diversity and in great numbers. Protozoa, amebas, spirochetes, and fungi are present. Some of the protozoa contain enzymes which digest the wood for the ter-

mites. Without this guest the termite could not survive on dry wood.

Because of lack of information on the habits of termites and of the infested regions, many buildings are erected annually without in any way providing for protection from them. After damage has occurred it is frequently a matter of great expense to rectify the error, to reconstruct the building, to make it immune from attack. One method has been, of course, to keep all wood from contact with the ground. Frequently, however, the termites will build a grayish shelter-tube over cement to reach the wood. These are easily seen and destroyed.

Because no known wood is immune to attack (the heart-wood of some trees is highly resistant), methods of chemical treatment have been devised by chemists of the United States Department of Agriculture. For wood in contact with the ground, the use of coal-tar creosote is recommended. For wood intended for use above ground, treatment with zinc chlorid has proved most effective.

Have Insects Ears?

Can insects hear? In general they do not respond to any sounds that we make, and as a result the conclusion has been reached that they are quite deaf. This is not a fair conclusion. True, you may shout at a fly as much as you

choose without exciting in it any evidence that you are heard. But there is nothing you are likely to shout that will be of much interest to the fly. Its lack of reaction may only prove that you are unintelligible to it. We, perhaps like the fly, only react to those sounds which interest us or which convey some meaning to us. To the fly you make but one more sound in the great quantity of sound made by humans which cannot possibly mean anything to the insect. It is not surprizing that it does not respond.

Experimenters have, however, found a few insects which respond to sounds which we can make. Silkworm moths have been found to lift their wings when an organ pipe was sounded. Every precaution was taken to keep the draft of air used to blow the pipe from directly reaching them. Failure to avoid a disturbance from this cause has led many observers to assume that the insects were responding to sound when they were in fact responding to the movement of air. A number of species of under-wing moths have also been found to respond to a high-pitched whistle, either by flying or by lifting their wings as if to fly. Two species of caterpillars have also been shown to respond to sound by motion of their bodies. This response has been definitely associated with hairs on the body. When these hairs are removed by singeing, or when they are made inactive by a coating of

water or of shellac, the response ceases. This does not mean, of course, that it is the hairs which hear, but rather that, as in the human external ear, they are connected with internal sensory organs.

Searching for what corresponds to an external ear in insects has not been very fruitful. There are few which have any organ that remotely resembles the external ear of the human. Crickets and katydids, however, have an earlike structure on their front legs, and investigation shows that these are connected closely with enlarged air-tubes such as are present in great numbers in every insect body for breathing purposes. The sensory organs associated with these cells are different from any other in the insect body. They are characterized by having the axis fiber stretched through the center of a hollow tube filled with liquid. There are large numbers of these cells near the ear on the front legs of crickets and katydids, and these are all connected to the central nervous system. They have every appearance of being intended as organs of hearing. Suspecting this, scientists have searched other insects for similar cells. These have in many cases been found, frequently in the most unexpected places on the insect's body, and not associated with any external organ obviously intended for hearing.

Suppose, now, that we are satisfied that these

organs are in fact organs of hearing. What guaranty have we that they are intended to hear the frequencies to which the human ear is sensitive? We are limited by a maximum upper range of 20,000 vibrations per second, a value that would be high for even an abnormal individual. Possibly the insect has a different range. Its organs of hearing might begin where ours leave off. It is fair to assume that insects should be capable of hearing the sounds which they themselves make, and Professor B. B. Fulton, of the North Carolina State College, has made use of this likelihood in his study of insect hearing.

Observing that certain species of crickets and katydids sing in unison, he determined to use this fact in his experiments. These insects keep such perfect time that the song of ten or a dozen is often mistaken as that of a single individual. Professor Fulton collected such insects in cages, and after satisfying himself that their singing was synchronous, he cut off the front legs of half of them just above the hearing organs. These insects he placed in an adjacent cage, far enough from the others so that he could distinguish the song from each group. He found in every case that the song of those with the sensory organs removed was entirely haphazard. They were like a group of deaf musicians playing in the dark. Occasionally a pair would get in their chirps together by accident, but they would

gradually depart from the synchronism again. The normal insects were always together in their song. This proves that, certainly in the case of these insects, they not only hear, but their sensory organs have been definitely located. There is every reason to believe that many other insects may also hear with less fully developed ear organs, which may not always be sensitive to the same sounds that affect humans.

Soil Erosion

One great farm loss which sneaks upon the farmer, more or less unawares, is soil erosion. The fertility of soil is, of course, depleted by the crops which it supports. This fertility can be replaced. What cannot be replaced, however, is soil washed away and out to sea. Not only is the plant food gone, but the soil itself which is necessary to support it. In this way many of our good farms are slowly but steadily becoming poor ones. The farmer's first warning is usually in bits of clay or rock protruding through the soil of what up to then had been a good, rolling field. Even then he may not take the necessary steps and sow the field with a suitable crop to preserve its soil.

"The Mississippi River alone," says Mr. H. H. Bennett of the United States Bureau of Chemistry and Soils, "delivers to the sea every year 528,000,000 tons of suspended matter, most

of which represents wash from the surface of the land, the richest part of the soil. In addition, more than a third as much is poured into the Gulf of Mexico in the form of dissolved matter, and it is not known how much more is swept along the bottom of the Mississippi. What is still more important is the material removed from the fields and deposited somewhere along this great watery highway to the sea, usually upon valley lands, where it is not needed, and in channels of streams where it does much damage. Every year this temporarily stranded material amounts to many times the combined quantity that enters the ocean."

It is estimated that erosion removes as much as twenty-one times the amount of plant food taken out by the crops.

In many cases land is cleared and no provision made for reforestation where it is perfectly evident that erosion will occur. It is in such places as these that the great gullies due to erosion occur. Nor is the damage restricted to this one locality. It may destroy good valleys by depositing in them. It may, as has happened, ruin established orchards of great value several miles from the eroded land.

Examples of erosion are common, as one sees in traveling about the country. Many eroded localities can be seen in a day's journey in almost any direction. In most cases nothing is being

done to prevent further damage. Many interesting cases have been reported. In one place where once stood a school-house there are now gullies a hundred feet deep. It is a desolate section, desolate beyond reclaiming. Much of the best bottom land in New England was permanently destroyed by the flood of 1927. There was spread over it a deep layer of loose sand and gravel of low water-holding capacity. Far up the Missouri River Valley, a region of 120 acres has been known to lose from eight to forty inches of soil since the clearing forty years ago. This has taken place slowly but continually. Each muddy stream flowing down the roadside is carrying off its bit of soil unless some provision is made to collect it. It is estimated by Mr. Bennett that soil erosion is costing the farmers as much as *$200,000,000 annually. This bill is presented to* the citizens of America every year. We are told that if this keeps up we shall soon be no longer a nation exporting farm products, in spite of our increasing farm efficiency through machinery.

All this can, of course, be prevented by proper scientific farm operation. In most cases the soil, prone to erosion, can be used to raise crops which will hold the soil in place. In many cases it can be prevented by cheap methods of terracing. In this way the violence of the drain is stopped and the soil is deposited quickly from

the slow-running water. The time has departed when we could think of the soil as free. Dirt is cheap only in small quantities. Fertile land on a nation-wide scale must not be dealt with thoughtlessly.

X

WE IMPROVE PLANT LIFE

Effect of Light on Plants

THE discovery of the profound effects attendant upon ray-therapy in the case of animal life has naturally turned the attention of botanists to similar studies in the case of plants. Their efforts have been well rewarded. A number of questions will at once spring to the mind of the inquisitive person. Since green vegetables have an anti-rachitic effect, is it because of their long exposure to the ultra-violet of the sun? Is the ultra-violet of the sun at all necessary or advantageous to the plant? We know that a plant utilizes carbon dioxid gas in its process of food synthesis, yet this gas, so necessary for plant growth, is poisonous to the human being when it comes in large quantities. Certainly, in this respect, the plant behaves very differently from the animal. Perhaps it also does so in numerous other respects. Let us see what the present state of our knowledge really is. First of all, we do not as yet know to a certainty what improvement, if any, in anti-rachitic effect may be conferred upon the plant by irradiation with ultra-violet. Presumably, however, there would be some benefit.

That the ultra-violet has an effect upon plant-growth directly, there is no question. But the effect is not always beneficial. Some plants do much better without it. In many cases it greatly increases the plant foliage. On the other hand, if we look into the effect of the infra-red, the light just off the other end of the visible spectrum, we find a very considerable change. The plant grown in this light assumes a slender, vine-like nature, and winds around its support. It behaves much like a plant grown in the dark, except that it remains green. Side-shoots and leaves have a tendency to curl up. The cell walls are thinner. The flowering is delayed. In general, the plant is weakened. As a result of such experiments it has been established that in general a plant is best off which is provided with all the constituents of natural sunlight.

Another interesting discovery regarding the effect of light on plants has been made in connection with the effect of varying the number of daylight hours. Here it can be said that the plant growth is hastened proportionately, provided that the plant is at the same time supplied with an extra amount of carbon dioxid gas. Plants, through the agency of the sun's rays, synthesize carbon dioxid and water into carbohydrates. Unless a sufficient amount of carbon dioxid is available to make it possible for the plant to utilize the extra sunlight hours, nothing is

gained. Clover, barley, and soy beans are plants which are notably benefited by extra hours of sunlight. Some plants, notably tomatoes, are benefited only by a few extra hours of the sun's rays. If carried too far, the sunshine treatment will result in killing the plant. Apparently plants, like humans, require a certain amount of rest for their well-being, and if this is not given to them they react in much the same way as humans.

It has often been suggested that the taste of vegetables or fruit grown in a greenhouse differs from that of those food plants grown in the open, because of the filtering out of the ultra-violet by the glass of the roof. It has been thought that the so-called "flat" taste of greenhouse plants might be explained in this way. Whether or not there is any foundation for this belief is still a question. If it could be definitely established that such is the case, an improvement in our hothouse products could be made by growing them under ultra-violet-transmitting glass.

Effect of X-Rays on Plants

The study of the effect of radiations on plant life would not be complete without including some experiments on the effect of x-rays. Much work in this field has been done by Professor T. H. Goodspeed, of the University of California. He has carried on extensive experiments over a

period of two years on the effects of these rays on tobacco plants. The results can best be summed up in his own words:

"The correct dosage of x-rays or of the gamma rays of radium applied to any tissue of the tobacco plant which is capable of growth or is concerned with the process of sexual reproduction is followed by variation.

"Some of the variations which can thus be reproduced are inherited, since they affect the character of hereditary material. The other variations are not in the same sense inherited, because they affect the amount rather than the quality of the hereditary material. From a scientific point of view both sorts of alteration are of interest, because they parallel the types of changes known to go on in the hereditary material of plants and animals in nature or under domestication.

"The dry seeds of the tobacco plant," Professor Goodspeed continues, "are very resistant to these high-frequency radiations. Only the heaviest dosage will kill them, but when the seeds have begun to grow, a relatively light dosage proves to be lethal. Such plants as survive are often chimers—or mosaics—some tissues containing one alteration in the hereditary material, others being different in this respect.

"This same type of effect follows treatment of the growing points of the stems of young

plants. Practical application of these results may be possible. If the horticulturist can obtain a similar mosaic condition in fruit trees, for example, then he could select the branch 'sports' which were of value or interest and propagate them by cuttings."

Public attention has already been called to the fact that x-ray treatments of immature sex cells of tobacco plants have resulted in great variation in plants resulting from the union of these plants. Work has been going on for more than two years on the effects of x-rays and the gamma rays of radium on seeds and seedlings and tissues of other sorts. Later generations have been grown from the original products of x-rayed sex cells.

More than 10,000 plants illustrating the effects of treatment on various tissues are now being grown in the botanical gardens of the university.

What the future may bring in the way of further development of such studies can only be a matter of conjecture. It appears, however, that such studies will be of the greatest interest and value to the human race.

Gassing Plants

The ripening effect which results from the gassing of certain fruits and vegetables with ethylene gas is already well known. Oranges,

tomatoes, bananas, and many others respond to this treatment. When potatoes are taken from the ground they will not immediately sprout. The dried-looking buds, which are in the eyes of the potato, require some time of rest before they are ready to develop. This rest period was for a long time thought to be a necessary element in the plant cycle. Now we know that it can be shortened by various means without harm to the plants which come from this seed. It was at first found that the ethylene gas, which hastened ripening, also had a mild stimulating effect on potatoes; it shortened slightly a dormant period. But the advantage gained was too slight to be of any value. Dr. F. E. Denny, of the Boyce Thompson Institute for Plant Research, has shown, however, that certain derivatives of ethylene are much more potent than the gas itself in this respect. Ethylene chlorhydrin and ethylene dichlorid are effective, as is also sodium thiocyanate. Good fortune is also in evidence here, in that these materials, being liquids, are much easier to handle than is the ethylene itself. The liquid, when used, is vaporized by blowing air across it. The vapor soon fills an airtight room.

The result of the treatment of potatoes by this method has been not merely to shorten the period of dormancy, but actually to eliminate it entirely. Potatoes taken from the ground can be

replanted as soon as they have been treated. This bids fair eventually to revolutionize potato-growing in this country. It will make the growing of two crops a year the rule over a large section of the country. It will not affect the far South, where this is already possible, nor the North, where the season would in any case be sufficient for but a single crop. In that large midway section, however, beginning with southern New Jersey, we may soon expect to see two crops grown regularly. Of this the late Professor J. T. Rosa, of the College of Agriculture, University of California, wrote:

"The practical application of the dormancy-breaking treatments will be used mainly in the Southern States and in California. From southern Jersey to Texas and as far north as the Ohio and Missouri Rivers, the growing season is long enough to produce two crops of potatoes a year. To do this economically it is desirable to use the potatoes produced in the spring crop as seed for the fall crop. Except in the far South, the period between the digging of the one and the planting of the other is too short for the tubers to pass through their natural dormancy. Hence the need for treatments to hasten sprouting.

"Another instance of the usefulness of stimulation treatments is the treating of seed shipped from the Northern States to Bermuda, Florida.

and California for planting a winter crop. This seed is dormant when received by the Southern growers, who can increase the earliness and yield of their crops by stimulation treatments. These treatments may also be useful in seed-growing districts. For seed purposes medium to small tubers are desired. The proportion of such tubers can be increased and the overly large tubers reduced by treatments that result in an increased number of stalks with a greater number of tubers per plant."

Temperature and Plant Life

The use of such chemical methods as the one just described is sure to be extended greatly now that an impetus has been given to research of this character by the success with potatoes. Methods of treatment for giving greater percentage germination of seeds will also be discovered. At the present time much is being done in the study of purely physical effects, such as that of temperature.

Temperature alone has been found to have a very marked effect on the dormancy period of potatoes. For many years it has been generally believed by farmers that keeping potatoes in cold storage for a few weeks would have the desired effect, and it has not been uncommon for farmers to put their seed-potatoes in cold storage for a short time before planting. Experiments at

the College of Agriculture, University of California, have shown conclusively, however, that such storage has in fact no value. There is little difference in the rate of sprouting after three or four weeks of storage at 40, 48, 55 and 70 degrees Fahrenheit. On the other hand, potatoes stored at 80 to 86 degrees Fahrenheit were ready for replanting in about three weeks. They sprouted rapidly, and the plants were above ground in twenty-four days. The usual dormant period is from three to four months. Different varieties respond somewhat differently to this treatment.

From the standpoint of reforestation, the Boyce Thompson Institute for Plant Research has made a valuable contribution to the hastening of germination of southern pine by means of special treatment. In Louisiana the low percentage and irregular germination of the pine has seriously hindered reforestation work. The treatment given the seeds consisted of stratification in moist peat moss at 0 to 5 degrees centigrade. Seeds so treated for one to two months gave 82 per cent. germination in twenty-two days, while seed not so treated gave but 41 per cent. germination in 100 days. The percentage of germination depends somewhat upon the species of pine, but in forty-eight days the after-ripened seeds of short-leaf, slash, and loblolly pine gave 62.60 and 70 per cent. germination,

respectively, while the control seeds, not so treated, had not appeared above the ground at all. The saving in time, money, labor and expense which this simple method promises is enormous.

Temperature appears also to promise a satisfactory treatment for cuttings intended for planting. A great deal of work has been done with holly cuttings at the Boyce Thompson Institute. The increasing popularity of holly for decorations during the Christmas season has resulted in a demand which the growers find themselves unable to meet. The result has been that an acute situation has developed where it is essential to increase at once the parent stock. Dr. P. W. Zimmerman has developed a method which promises a rapid increase in these plants by cuttings. The cuttings are stored from four to five months in about five inches of half-and-half peat moss and sand. The temperature is kept between sixty-five and seventy-five degrees Fahrenheit. Using current-season stems, these were so accelerated as to produce berries the first season. As the propagation of holly from seeds has been very difficult, and as they did not respond well to propagation by cuttings as usually carried out, this treatment will prove of great value to the growers.

These few examples of what has been accomplished by gas and temperature treatments in the

matter of plant propagation are only suggestions of what the future may bring. The possibilities are indeed fascinating. We may yet bring Nature under our command.

Camel Plants

The camel has long been thought of as a symbol of dryness. His ability to live for many days without water has been considered remarkable. But, after all, compared with some other forms of life, his feats in this respect are as nothing. Many plants can exist without water for months. But, you say, these are plants, not animals. Yet, nevertheless, the fact that a camel walks and these plants do not does not make their feat the less remarkable.

In thinking of camel plants one at once calls to mind the cactus plants of the desert regions. These have a remarkable ability to store water, being admirably designed for this purpose. First of all, their roots spread out over a wide area just below the surface of the soil. This enables them to absorb immediately great quantities of water from even a slight rainfall. Their thick leaves, covered as they are with a coating which may almost be described as rubber-like, are intended to give up a minimum amount of this water, which is stored in the fleshy part of the plant. So well worked out is the system of water collection and retention that a cactus plant may

be uprooted for months and still carry on its life. Some have even been known to live a year and a half after uprooting.

But not all plants intended to survive on a minimum of water are necessarily desert plants. There are many dry spots, such as thinly covered rocks, where the plants must show this same ability. Every gardener also knows the great advantage which many weeds have in this regard. Purslane, for instance, will take root again days after it has been hoed loose.

Again there are those plants which must store water against a seasonal drought. This is often done by means of underground bulbs, as in the case of the wild onion. Describing this noteworthy example in point, Professor E. L. Pickett, of the State College of Washington, writes:

"A wild onion, common throughout the western part of the United States, produces its leaves and clusters of light pink flowers in April. By the first of June both are dead and dry. The bulbs, usually less than one-half inch in diameter, are six to eight inches below the surface. Through the summer months the soil becomes dust-dry, and there is no rain before September or October. A hundred of these bulbs were carefully taken up one May. They were weighed and then kept in a dry room for more than eight months. At the end of that time they showed only an insignificant loss of weight. At another

time a number of nice specimens were taken when in full flower. They were carefully pressed and dried, without crushing the bulbs, and put away in a dry-storage room. Twelve months later these specimens were taken out for examination and were found with clusters of new flower buds. No water other than that in the bulbs had come near these plants at any time during the year."

The amount of water which it is possible to store in underground roots, stems, bulbs, and so on, is enormous. Roots weighing more than fifty pounds are not uncommon with some members of the gourd family, and these roots are found to be 80 or 90 per cent. water. The retention of water in such underground parts is often aided by coverings that are quite cork-like in their nature and almost impervious to water.

Other plants survive dry seasons by reaching maturity in the short rainy season, producing seeds, and dying. The seeds, which contain but five to ten per cent. of water, are carried over to the next rainy season. Common grains are often able to live for fifteen or twenty years and germinate successfully. The stories of seeds taken from ancient tombs and made to germinate after centuries probably have no basis in fact. Most seeds must be planted immediately after maturity.

XI

NEW TRICKS IN CULTIVATING THE EARTH

Fur-Farming

As is the case with almost every industry, the farm has constantly opened to it the possibility of producing new products. The alert scientific farmer is never slow in taking advantage of them. One of the latest of these farm opportunities is fur-farming. In the past such animals as fox, mink, beaver, and lynx have been farmed by specialists with profit; but such enterprises have presented little opportunity to the busy farmer. The latest fur to be farmed is the muskrat. This many farmers are well equipped to produce without cost for labor, food or housing.

Only recently has the muskrat been worth considering. The trapper who could get only fifteen or twenty cents for a muskrat pelt spent his time on larger game. The muskrat was left for the farm boy. But at the end of the World War, when this animal brought as much as ten dollars a pelt, and later stabilized at around two dollars, it took on a new prominence. Further, the furriers found the pelt an easy one to dye in such a way as to resemble more expensive furs. It now masquerades under various

fancy names. This opened up the opportunity for the farmer.

The muskrat lives in swamps and marshy land, places which are of little value normally. Perhaps some such places could be drained and made to produce a grain or grass crop, as many have been; but there is an enormous acreage that it would never pay to attempt to develop. Such swamps may produce at best a few tons of coarse marsh hay, hardly worth gathering. A surprizing number of farms have at least a few such acres. These are the places where the muskrat thrives. He finds his own food for the winter in the grasses of the swamp. He stores up his own winter food supply. He is not subject to any known disease. It is evident that the muskrat farmer is due to have but little care of the animals. In the event that the food supply runs short, as might happen if the land were allowed to become overstocked, a bushel of turnips or carrots will feed a muskrat for three months.

The only precaution which the farmer must take for the care of the animal is to protect it from its natural enemies. Other animals can be kept out of the muskrat farm by surrounding it with a tight wire fence a few feet high and buried a few feet under ground. Such a fence is not necessary to keep the muskrat from run-

ning away, for he is living under natural conditions and will have no desire to migrate.

The farmer's only concern, once his farm has been established, is to gather pelts. As the female will produce from twenty-five to fifty young a year, it would seem that this catch should occupy his winter months.

In Canada this type of farming is being encouraged by the Government. Waste lands are being leased out for the purpose of such farming, at the rate of twenty-five cents an acre for the first three years and one dollar an acre per year from then on.

The muskrat industry has reached a high state of development on the coast of Maryland. Much of the land is subject to tidal overflow and is valueless for any other purpose. Of these marshes a United States Department of Agriculture Bulletin says: "Now, owing to the increased value of fur, many of the marshes, measured by actual income, are worth more than the cultivated lands in the same vicinity."

One should not forget that in this district the animals are also sold for food under the name of marsh rabbit. There seems no possible objection to this, as the muskrat is clean in its feeding. It is almost wholly herbivorous, living on the weeds and grasses of the marsh. Its only animal food is mussels and slow-moving fish such as the carp. The table-use of the muskrat offers

an additional income which the farming of no other fur-bearing animal produces.

It is only to be expected that as civilization advances we should turn to fur-farming. In the early days man's food depended upon his ability as a hunter, and upon the natural vegetation found in his neighborhood. The science of agriculture has now changed all that. In the same way it will remove our dependence for furs on the haphazard methods of the trapper. The trapper can now settle down as a regular member of the community and make his living off his own fur-farm.

Ocean Farming

As we depend no longer for our furs upon chance, neither do we now depend upon the occasional foraging of seafarers for our ocean foods. The farmer has gone to sea. No longer do we need to depend upon natural conditions for a good crop of oysters. The bivalves are now produced by artificial cultivation. At the proper season the baby oysters, or spats, are transplanted to suitable waters, there to mature, just as plants might be set out in the garden. New areas are constantly being brought under cultivation; the oyster-beds along Long Island, thus formed, extend for miles. No longer is it anybody's oyster, for these beds are protected by law just as the farmer's fields are protected. In

Japan and in France the oyster is even more intensively cultivated than in America.

Oysters whose shells are suitable to make buttons are also farmed. The United States Bureau of Fisheries operates a large experiment station on the Mississippi River to assist the pearl-oyster industry. Hundreds of tons of shells are produced annually by artificial cultivation.

When one realizes that five-sevenths of the earth's surface is covered with water, it is evident that the increasing population is sure to make ocean farming more urgent. This offers a solution to the problem of food supply for some time to come, a fact which is more evident when one realizes that farming on the ocean is not confined to a plane, as is earth farming, but is really three-dimensional. Every ocean level has its own kind of life. As we go down deeper and deeper we find constantly changing ocean inhabitants. It is a multi-storied farm. Scientists are now experimenting with the propagation of the useful sponges, and with the raising of tortoises for tortoise-shell and for food.

In the past we have simply harvested those things which the ocean had to offer. So great has been this industry, however, that there has been taken from the waters of the United States and Alaska about three billion tons of fish annually. Little attempt has been made toward the restocking of this vast food store. In the case of salmon

the time has come, however, to give more serious thought to the farm aspect of the problem. Protection during the spawning season is not enough. In the end we must expect to farm our fish. Two of the oldest salmon rivers in the country, the first to be fished by white men, were the San Joaquin and the Sacramento. Through the water-power projects that have been constructed along these rivers the spawning ground has been reduced from a length of about 6,000 miles to less than 600. This is a problem of ocean farming that needs immediate attention.

We have already been warned of the diminishing supply of whales. Here also is a problem of ocean cultivation. In the future we may expect to see even the whaling industry put upon a farming basis. If the constructive efforts of man are not extended to this and similar fields, many members of our sea fauna may soon disappear.

Forestry

We have long since passed beyond the stage where we depend upon foraging for our food, and are in a stage of transition as regards our furs, while we are fast approaching that stage in forest products. We have made terrible inroads upon our natural forests, and must now begin to farm trees just as we do other plants. No longer can we rely upon bounteous nature to

supply our needs in this respect. Her methods were never intended to cope with the devastating mechanical devices which man has devised At the present time there are in the United States no less than 300,000,000 acres of unused forest land. We must begin to cultivate this.

One of the drawbacks to forest farming in the past has been the feeling that one must wait too long for returns. This is because the problem has not been sufficiently investigated. If one were to start a forest of oaks, or some other slow-growing tree, the forest products might not repay one for the work in a lifetime, even remembering that there is much to be taken out of a forest before the trees mature. Such projects are for those authorities whose life is more extended. Many towns and villages have taken over and managed forests scientifically. Those that have done so over a number of years have profited greatly. There are villages in the United States at the present time which do not tax their residents, because all expenses of local government are met by products from municipal forests. The same is true in many places in Europe. Besides this source of profit, the forests offer a place of recreation to the inhabitants of the section. It is a venture that no progressive town should overlook.

In much the same way corporations whose business requires forest products, and which are

well established, sometimes undertake to manage their own forests. Paper-mills have in some eases planned their own forests to take eare of their need of spruee. Railroads are in some eases growing their own ties. The United States Forest Serviee has under its control large forest areas at the present time. These are being admirably managed.

For the individual there is here also a possible souree of profit. It has been found that farmers living in plaees remote from a natural supply of Christmas trees—in Ohio and Indiana, for example—can realize as much as $300 an aere annually by growing suitable trees. The field is plowed as for any other crop, and seedlings are planted. It requires about five years for the erop to be suitable for Christmas trade. The *profit of $300 is figured, however, from the time* of planting. The first erop is only a thinning of the trees, whieh is neeessary to permit the proper growth of those remaining. The area ean be thinned every year up to about twenty-five years, when the erop will be matured. As the trees grow larger, they are, of eourse, sold for lumber.

Forest eonservation does not mean leaving the forest alone and taking nothing out of it. It means seientifie management. The stand of trees must be thinned periodically. In the beginning a thiek stand is desirable, as it forees the trees

to grow higher to reach the sun's rays. The weaker ones, which fall behind, are then eliminated in order that they may not rob the stronger, healthier trees of needed food and light. In this way there is afforded to the forester a constant income, once the forest is established.

Transplanting Birds

In the single year 1928 more than half a million birds were imported into the United States. The total number was 682,308. Since 358,449 were canaries and 56,307 were parrots, the number of imported birds intended to be freed is reduced by this amount, as canaries and parrots are imported mainly as cage or exhibition birds. It still leaves a large number of birds which were set free, however. Of these, quail constitute a large proportion, 84,915 having been imported. Next in number stand pheasants, ruffed grouse, and ducks. When one realizes that in addition to these importations there were also going on experiments in transplanting birds within the boundaries of the country itself, the magnitude of the undertaking can be realized.

Despite the time and money thus spent, however, the factors which determine the success or failure of such experiments are not known. There are those who do not favor attempts to bring in any new birds because of the possi-

well established, sometimes undertake to manage their own forests. Paper-mills have in some cases planned their own forests to take care of their need of spruce. Railroads are in some eases growing their own ties. The United States Forest Service has under its control large forest areas at the present time. These are being admirably managed.

For the individual there is here also a possible souree of profit. It has been found that farmers living in plaees remote from a natural supply of Christmas trees—in Ohio and Indiana, for cxample—can realize as mueh as $300 an acre annually by growing suitable trees. The field is plowed as for any other erop, and seedlings are planted. It requires about five years for the crop to be suitable for Christmas trade. The profit of $300 is figured, however, from the time of planting. The first crop is only a thinning of the trees, which is necessary to permit the proper growth of those remaining. The area can be thinned every year up to about twenty-five years, when the crop will be matured. As the trees grow larger, they are, of eourse, sold for lumber.

Forest conservation does not mean leaving the forest alone and taking nothing out of it. It means scientific management. The stand of trees must be thinned periodically. In the beginning a thick stand is desirable, as it forces the trees

to grow higher to reach the sun's rays. The weaker ones, which fall behind, are then eliminated in order that they may not rob the stronger, healthier trees of needed food and light. In this way there is afforded to the forester a constant income, once the forest is established.

Transplanting Birds

In the single year 1928 more than half a million birds were imported into the United States. The total number was 682,308. Since 358,449 were canaries and 56,307 were parrots, the number of imported birds intended to be freed is reduced by this amount, as canaries and parrots are imported mainly as cage or exhibition birds. It still leaves a large number of birds which were set free, however. Of these, quail constitute a large proportion, 84,915 having been imported. Next in number stand pheasants, ruffed grouse, and ducks. When one realizes that in addition to these importations there were also going on experiments in transplanting birds within the boundaries of the country itself, the magnitude of the undertaking can be realized.

Despite the time and money thus spent, however, the factors which determine the success or failure of such experiments are not known. There are those who do not favor attempts to bring in any new birds because of the possi-

bility of bringing with them new bird diseases or bird pests. On the other hand, there are those who, John C. Phillips says, "would bring in anything from a button quail to an ostrich without any regard for the general suitability of the species." Mr. Phillips has made a comprehensive study of this problem.

In general, transplanted birds behave in four rather distinct ways. They may stay around a short time without nesting and then suddenly disappear. This often happens in what would appear to be a particularly favorable environment. Where they go is never determined. California quail brought into the Eastern States behave in this way, as do also some European song-birds.

The next class is one of partial success. The birds may nest the first season, but in succeeding years fail to do so. The original birds will be found in the neighborhood for a number of years. This behavior is characteristic of European partridges released in Massachusetts and Connecticut.

The third class attain a local success. They may nest and increase locally for a number of years, but they do not spread. Eventually they are likely to disappear suddenly and completely, perhaps as the result of an especially hard winter.

The fourth class is that of complete success.

The birds are for a period free from natural enemies and diseases common to the place of origin. As a result they increase to the proportions of a pest. Eventually, however, they come under control. This was the case with the English sparrow. Released in America by the Brooklyn Institute in 1850, these birds reached their height about the beginning of the century. They have now been brought under control. The history of our present starling pest is somewhat the same story. Many attempts were made to introduce this bird, beginning as far back as 1872, but all of them were unsuccessful. The present starlings, found in almost every part of the country, are all descended from fifty pairs that were released in Central Park, New York City, in 1890 and 1891.

In the case of migrating birds the difficulty of transplanting is much greater than otherwise. Usually when they go south in the fall it is never to return. This has been the case with Egyptian quail. Many thousands of these were released in this country between the years 1870 and 1880. Mallard ducks, many of which have been released on Long Island by sporting clubs, likewise never return. They appear to go north up the Mississippi River along with others of their kind on their way to Canada.

A very thorough study of this whole problem is now in progress by the Biological Survey.

Complete account of every bird entering the country by importation is kept, and in addition an extensive program of bird banding is being carried out with the aid of experienced amateurs in all parts of the country. Many thousands of birds are being banded annually and their movements determined by subsequent trapping. Since the birds are of course uninjured, they are freed again, later to be again reported by a similar means. Some have already been reported several times in various localities. It is thought that in this way the facts about bird migrations, the possibilities of transplanting, and so on, will be definitely established.

Farm Waste

The farmer has become a scientist, and therein lies his present difficulty. During the period 1900 to 1920 the falling off of farm products in this country led to the establishment of all kinds of agencies to educate the farmer in scientific methods of agriculture. The agricultural press, farm organizations, agricultural colleges, extension service and experiment stations, State and Federal agricultural departments, have all joined in the spread of such knowledge. They have done their job well. The census of 1925 showed, for the first time in the history of the nation, a decrease in acreage under cultivation. There was a decrease of 13,000,000 acres over

that harvested in the period 1919 to 1924. The acreage is still rapidly decreasing. In spite of this, larger crops are produced than formerly.

"Agricultural production as a whole," says Mr. O. E. Baker, of the United States Department of Agriculture, "was 14 per cent. greater in the period 1922-26 than in the period 1917-21, whereas population increased less than 9 per cent. in the same periods; in other words, the increase of agricultural production was more than 50 per cent. greater than the increase of population.

"Moreover," continues Mr. Baker, "the acreage in pasture on farms has decreased (but not total pasture), and the number of horses and cattle and hogs has decreased notably; indeed, beef cattle are less numerous than at any time during the last forty years, and there are about the same number of hogs in the United States as forty years ago. Furthermore, the number of farms has decreased since the World War years, the farm population and the number of farm laborers has decreased even more, and the average acre-yield of crops has increased only slightly."

Fewer farms, fewer acres, fewer animals, yet more grain, more meat, more dairy products are available. How can this be?

To begin with, the advent of the farm tractor has filled a double rôle. It has cut down greatly

the amount of labor necessary on the farm, and it has relieved those acres formerly needed to grow feed for horses used on the farm. The new combine, now coming into use, will further cut down the necessary farm help, and leave an oversupply of farm labor for some time to come. Horses and mules are being raised in only about half the numbers necessary to replace those which die.

Now, how do we get more milk from fewer cows, more meat from fewer animals? A century ago our best cows probably gave not over 2,000 pounds of milk annually. Our best dairies to-day average 5,000 pounds per cow. Some cows even reach the 10,000-pound mark. A 5,000-pound cow eats much more than half the food required for a 10,000-pound cow; probably two-thirds as much. It requires just as much care. The change is the result of scientific breeding and feeding. More meat is available with fewer cattle because they are killed younger. The fastest growth is in early age. The proportion of calves slaughtered as compared to the number of older animals is rapidly increasing.

Other causes of the change are such things as better insect control, the greater and more intelligent use of fertilizers, and the introduction of fertilizers which are scientifically correct for the particular land under cultivation. Then, too, there have been introduced new and hardier

plant varieties—varieties immune to various diseases, and varieties which mature quicker. Our changing food habits are also a factor in this farm problem.

This all means that many of our present farmers will have to find new occupations or that a new source of income will have to be provided in some fashion. Scientists are working on the question. The most likely solution at present seems to be in the utilization of farm waste as by-products. Insulation board is now being made from wheat straw, rayon is being made from corn stalks, and many other marvelous things are taking place which can best be described in a review of chemistry. At present all these promising developments are in the experimental stage. They hardly offer more to the farmer for his waste than he can realize by plowing it under as fertilizer. They offer an interesting future for the farm, however; the farmer may yet find himself a dealer in raw chemicals.

Mulching Crops with Paper

For many years it has been the custom in the Hawaiian sugar plantations to leave the crop refuse, such as leaves, tops, etc., between the rows. This mulch served the double duty of conserving the soil moisture and keeping down the weed growth. Because of the temporary nature of such mulch, it occurred to Mr. C. F. Eckart,

manager of one of the plantations, to place between the rows a cheap grade of asphalt paper. This was so successful that he later completely covered the field. The stiff shoots of the sugarcane would penetrate the paper, while the weed would not. This was later extended to the pineapple crop, and now it is estimated that 90 per cent. of this crop is so mulched. Holes are made in the paper, so that the pineapples can come through.

Because of the success met with in Hawaii by mulching with paper, many experiments have been carried out in the United States on various vegetables, particularly by Mr. L. H. Flint. In general he has found the production increase to range from about 30 to 500 or 600 per cent.

The reasons for this increase in crop production are many. The paper mulch has the property of keeping the top few inches of soil much more moist. It has been found that twelve days after a rain the mulched soil may contain as much as 20 per cent. more moisture than the unmulched in the same neighborhood. Where weeds were allowed to grow, it would doubtless be much greater; for in dry times the chief damage which weeds do is to dissipate the moisture in the soil through their leaves. Where the plants are allowed to grow through perforations, even a light rain, ordinarily of little benefit, is of great value. What water there is runs through

the holes directly upon the plants, where it is needed.

It has also been found that the temperature under the mulch is on the average about 10 degrees higher than in the open. This produces a semi-tropical condition which allows plants to be grown many miles north of their usual habitat. It also causes plants to mature weeks ahead of their usual time. This not only brings better prices, but may frequently allow two crops where otherwise only one would be possible. It is also found that the increased temperature causes nitrate-forming bacteria to work faster. Plants taken from mulched soil are higher than others in nitrates.

The cost of labor is obviously lessened. There is neither hoeing nor weeding to be done. It is also found that plowing is unnecessary. Plowing is in any case largely for the purpose of keeping down weeds, and in the mulch experiments it is so far found that the crop does not suffer from its lack.

At the present time there are coming on the market many papers especially prepared for this purpose. Such papers may be left in place for as long as five years. Some have perforations which will permit moisture to pass through and yet check weed growth. Almost any grade of asphalt paper will give most of the benefits of these special mulching papers; much work, how-

ever, is now being done to develop a lasting cheap paper for this purpose.

When the plants are protected from weed competition, they develop, as a rule, to a larger size. They are also protected from many plant diseases and insects. In fact, the mulch gives many of the benefits of a greenhouse without the large cost. It will, of course, never replace the greenhouse, which offers all these advantages in much greater measure and supplies a year-round occupation to its operator.

Farm Engineering

Farm engineering is a new name for intelligent farm planning. Too often a farmer works too much with his back and too little with his head. He finds himself just so far behind that he never has time to stop to think his way out of the muddle. It is farmers of this kind who are falling by the wayside in the present race.

There are many engineering factors in producing, harvesting, and marketing farm products. Let us consider a few of them. Shall the farmer clear more of his land for crops? To do so might cost him \$150 to \$200 per acre, and if he undertakes it he figures that he has permanently added this value to his farm. Perhaps he has not the proper facilities to care for the additional land. It may result in poor management for the rest of his acres. Perhaps for \$40 an acre he might

have drained some land now in operation, or he might have irrigated some land, and so increased its efficiency from 10 or 20 per cent. to 100 per cent. without laying up unnecessary work for himself in the future. Drainage and irrigation are as a rule given less thought than increased acreage. The wise farmer to-day does not buy acreage. He buys fertile land with an eye to the cost of operation.

Frequently the farm road may deserve attention. The farmer may find that the number of loads to harvest a crop may be greatly decreased by improving the road to his fields. This may be done with easily available stone. It may be done by easing the grades.

It is not uncommon for the load that a farmer can draw to market to be limited by the road to his own gateway. From there on he finds easy grades on hard-surfaced roads. Yet year after year he takes undersized loads to town. A little work in an off season would alleviate this condition for all time. Proper engineering might even suggest a hard-surfaced road in his own yard. The movement of the product is one of the first considerations in locating a factory; it should be considered also on the farm.

Then, too, there is an engineering problem in the location and management of the water supply. The location is often inconvenient. The proper storage and care of his farm machinery

may save him hundreds of dollars a year. The same is true of his harvested crops.

Where a farm employs several laborers, a division of labor is often desirable, giving the men charge of those things in which they evince a particular interest. This is but following out the plan of the management of any business. The successful farmer must show executive ability.

The farmer cannot be expected to know everything, but he should know where to find out those things which will help him. If he lacks engineering knowledge he will probably save himself many dollars in costly errors by calling in an engineer. Those who specialize in this kind of engineering are now available. It offers a new vocation for the engineer, which may be expected to become popular with the farm boy, suitably gifted, who finds that modern methods have left no place for him on the farm, or who prefers work of this type. The surveyor's instrument is already taking the place of sighting over posts.

OUTLINE OF SCIENCE

PART II

THE

WORLD'S ESSENTIAL KNOWLEDGE

VOLUME II

OUTLINE OF SCIENCE

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PART II
MAN'S MATERIAL ACHIEVEMENTS

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OUTLINE OF SCIENCE

PART II

I

SOMETHING FOR NEARLY NOTHING

Chemical Loafers

ONE of the most amazing developments of the age, in the field of chemistry, is the rate at which we are discovering methods of extracting new chemicals from the earth's surface and finding uses for them. It is but a few years ago that helium was unknown on the earth. Evidence of its presence in the stars was given to us by the spectroscope, but there was no indication that there was any of it present here until it was discovered by Sir William Ramsay in 1895. In 1914 there was gathered together on the earth as much as two liters of helium for experimental purposes. The cost of these two liters of gas was at the rate of about $50,000 per cubic foot. To-day we obtain helium from the natural gas of oil wells at a cost of about twenty cents per cubic foot and fill great airships, such as the *Los Angeles*, with it. That is but one of the

chemicals, unknown fifty years ago, that modern science has ferreted out and put to work.

Aluminum, the common kitchen-utensil material, was hardly known half a century ago. There was perhaps less than a pound of pure aluminum on the earth. It was more expensive than gold, yet there was no use for it except in the laboratory. Aluminum is present everywhere in the materials of the earth's crust, in the form of aluminum compounds. When a cheap method of separating out the pure aluminum from these compounds was found, there were uses enough for it. There are many uses when it can be made into kitchen pans to sell for ten cents, but few when it costs two or three hundred dollars a pound. Another element put to work!

Chromium was the most useless metal imaginable until methods were found for using it. Its first job was in making a high-resistance alloy for use in electrical heating devices. Your toaster uses such wire. The man who discovered this wire did so under the most discouraging circumstances. The first chunk of chromium he obtained defied working. It broke every tool he attempted to use on it. He had to devise entirely new methods in order to handle it. Now we have it under control. We are able to plate it on other metals. It gives an almost indestructible finish. When plated on gears they are practically re-

sistant to wear. It gives a beautiful mirror-like finish which does not tarnish. Another element has found a job!

But there are many elements which are not yet put to work. Beryllium is usually thought of as rare. Seven years ago it would have cost $5000 a pound to produce. To-day it costs but $50 a pound and could be produced much more cheaply if there were any use for it. It is a plentiful material, altho you have probably never seen any of it. It is about two-thirds as heavy as aluminum, the color of steel, easily polished, and non-tarnishing in air, and when alloyed with other metals makes them hard and non-corrosive. Such a material should find plenty of work of some kind.

Titanium is another metal which is usually considered a rare element, but there is half again as much titanium as carbon on the earth's surface. Yet not more than a millionth as much titanium is produced annually as carbon in the form of coal alone.

Cæsium, columbium, dysprosium, erbium, europium, gadolinium, gallium, germanium, hafnium, holmium, indium, kryton, lanthanium, lutecium, masurium, neodymium, praseodymium, rhenium, rubidium, ruthenium, samarium, scandium, terbium, thallium, thorium, thulium, xenon, yetterbium, and yttrium are all chemical elements which most of us hear of but once

in a lifetime outside the chemical laboratory. Yet they all have the same chemical status as iron, gold, lead, and so on; elements with which we are quite familiar. Nor, as has been pointed out, are these elements so rarely heard of because they are necessarily rare. It is because we have found no use for most of them.

Occasionally we find some minor employment for such unusual elements. Argon, once considered rare, is now thrown away in actual tons of gas each day as a by-product of nitrogen-fixation plants. Its only use of importance so far seems to be in gas-filled incandescent lamps. Here, altho used in very small quantities, it is estimated that it saves for us $400,000,000 annually. Its great possibilities are not yet realized even in men's thoughts.

Other rare elements may be working for you to some extent. Thorium, present in minute amounts on the filaments of radio tubes, saves millions of dollars annually. Iridium is another practically unknown material, yet you may have some of it about you. It is used in springs for the fastening of jewelry, in the nibs of fountain pens, and in fastening false teeth. You may also have some cerium in your possession. It is used in the sparkers of cigaret lighters.

But these are only minor jobs. The potentiality of these elements is as yet wholly unknown. At the present time it is estimated that only

two-tenths of the ninety-two elements are being used. It will be the chemists' business in the next few years to add to this number. If we are to judge by the important developments which have followed the introduction of new elements into commerce in the past, we may expect to see revolutionary changes in the future. Perhaps the balance of world power may eventually hinge upon the possession of materials which to us to-day are little more than names.

Hydrogen—The World's Smallest Giant

While many atoms have thus been shirking, hydrogen, the lightest of all elements, has been greatly overworked. Most of us could probably name offhand but one single use of hydrogen—for floating balloons or dirigibles in the air. This depends only upon its lightness, for, consisting as it does of but one positive and one negative particle, it is approximately only one-fifteenth as heavy as air.

But floating lighter-than-air craft is an insignificant part of the work which this gas can do, and depends only upon its property of lightness. It can do heavy work as well. Long ago it was found useful in the manufacture of transformer iron. In an atmosphere of hydrogen the iron is prevented from oxidizing, and consequently scaling, when it cools. The hydrogen also burns out much of the carbon in the iron, leav-

ing a more desirable product for transformer purposes.

Now a new and important use has been found for it in welding. Hydrogen is made commercially by separating the hydrogen from the oxygen in water. Passing an electric current through water separates it into these two components. Now, if the two are again combined in a flame, the energy originally required to separate them is given out again, resulting in heat. This has led to oxy-hydrogen welding. Further, it has been found that if the weld is made in the presence of a hydrogen atmosphere a better union results. The material is prevented from oxidizing. One would think that these two jobs were enough for hydrogen to perform in welding, yet still another has been found. If the hydrogen is passed between the terminals of a powerful arc, the molecules will be split up into atoms. If these are brought into the flame, they recombine, giving up intense heat. They have transferred the energy of the arc to the flame. Thus hydrogen performs three jobs in welding alone.

This new method of welding threatens to revolutionize our handling of metals. Formerly large motor and dynamo cases were cast. Now not more than one per cent. of them are cast. They are fabricated by welding. With the modern torch the metals can be made to flow and

bend. They can be handled as easily as one would handle cardboard. This method of welding promises to displace the noisy riveting hammer in the construction of our skyscrapers.

In brazing, hydrogen has another function—as a flux. In an atmosphere of hydrogen, melted copper will flow into almost inconceivably small cracks. Thus brazing to-day is usually done in a hydrogen atmosphere. Hydrogen is also the best of our gases for purposes of cooling; for this reason it is often used in the closed cases of heavy-duty motors and generators.

But hydrogen does not give all its energies to the electrical field. It is used in the making of gasoline and benzine from coal. This is called the hydrogenation of coal. It is used in the making of ammonia in the synthetic-fertilizer industry. In this way it is of immense benefit to the farmer. It also has great value in the hydrogenation of cottonseed oil. The atoms of hydrogen are added to each molecule of oil to make the solid lard-substitute so common nowadays.

In addition to all these commercial uses it is this gas which has added most to man's knowledge of the structure of atoms and of the universe. Being the simplest atom in structure, consisting of but two parts, it is the easiest to understand, and conclusions derived from a study of the simple structure can be applied to the more complex atoms afterward. In this way

it has been possible to deduce much of our information of the universe around us.

Thus the smallest and lightest of our elements finds the most work to do; and not light work, either. It can, by its heat, cut through fifteen inches of steel, or it can float a child's toy balloon gently upward. It can make a useless oil of value as a food, or it can add to our knowledge of the stars. If our remaining elements were a tenth as useful we should not recognize our world if they were put on the job.

Steel Made with Air

The statement that our entire modern civilization is built upon iron and steel is indeed trite. The fact is so obvious as to need no expression. To say, then, that any addition to our knowledge of steel is of the utmost importance, is likewise unnecessary. It is a subject which is immune from debate.

Our knowledge of iron and steel forms a branch of modern chemistry. To begin with, we know that iron combines very readily with oxygen. It is this process which forms iron rust. Iron rust is, in fact, the material which we dig up out of our iron mines. The first job, then, in the production of iron is to get the oxygen out of the iron and have the pure iron left. This can be done by a method of substitution. When the iron rust is heated in the presence of carbon,

the carbon replaces the oxygen in the metal. For many years heating the metal with charcoal was the method used. Now coke is generally employed.

The metal which results from this process is usually saturated with carbon. It holds the maximum amount—about four pounds per hundred pounds of metal. Such material is called pig-iron. It is a convenient raw material with which to start in the manufacture of any other type of iron alloy or steel. It melts and flows readily.

To understand just how this pig-iron is used in the manufacture of all kinds of steels it is first necessary to know just how these are defined. When iron contains no carbon, or a trifling amount, it is called wrought iron. This is the material which the blacksmith is able to pound out on his anvil. It is a relatively soft material and easily worked. Structural steels are those which contain up to .75 per cent. of carbon. Tool steels contain from .75 to 1.25 per cent. carbon. Other steels contain up to 2 per cent. carbon. Cast irons contain from 2 to 4.5 per cent. carbon; pig-irons from 3 to 4.5 per cent., and foundry irons from 2.5 to 4 per cent. carbon.

The foundry irons are made by merely reheating the pig-iron. In this way some of the carbon is removed, and the resulting material is less brittle than the pig-iron. Increasing carbon content always means that the material becomes

harder and more brittle. Decreasing carbon content means a softer, more malleable product.

To make steel it is necessary greatly to reduce the carbon content. This was for a long time a process so costly as to be prohibitive. It was the discovery of the so-called Bessemer process, named after the inventor, which brought steels down to the point where they could be made as cheaply as iron. This discovery led to our modern machine age. Without it we would have none of our skyscrapers and vast bridges of today. We should not even have our automobiles as we know them. If made at all, the price would be prohibitive. The process is merely that of burning out the carbon in the iron by passing air into the molten liquid. This, with the carbon, forms a combustible mixture, which actually heats the metal far above its original temperature. Controlling the amount of carbon is then accomplished by merely controlling the amount of air which passes into the molten metal. Thus steel of any character can be made at will at only the cost of pumping in the air. The discovery revolutionized the entire iron and steel industry. Without this process it was necessary to heat the metal over long periods in order to burn the carbon out—a costly procedure.

This single simple discovery has probably affected the mode of our lives more than any other. There is still much room for improvement.

Methods of heat-treating, drawing, rolling, and so on, are being constantly improved. Yet the structural steel of to-day has a tensile strength of only about 80,000 pounds per square inch. Our best piano wire has a tensile strength of over 400,000 pounds per square inch. Theoretically, steel can have a strength of as much as 5,000,000 pounds per square inch. The best we can reach, by expensive methods, is but one-tenth of this. There is surely room for improvement here. There is still an opportunity for a discovery as great as that of Bessemer.

Inoculating Metals

Of late the attention of the metallurgist has been directed toward the study of alloys. When two metals are mixed we do not have, as a result, a metal with the weakest attributes of each. It is not the story of the chain being no stronger than its weakest link. Neither do we combine in one metal the best properties of each. We may, in fact, obtain many different results. We may have a material whose properties are as different from those of either of the metals combined as would be those of a wholly new metal. And this may in turn depend upon just what percentage of each is present. A small variation in the ratios of combination may make a profound difference. This makes the study both interesting and, usually, profitable.

During the present century the steel industry has gained greatly from the introduction of alloys. One of the first of these new steels was vanadium steel. At that time only a small quantity of vanadium had ever been obtained. It was more expensive than gold. It was found, however, that a small quantity added to iron would produce a very hard metal. The metal, unlike high-carbon iron, retained much of its toughness. While the amount necessary was so slight that the term "inoculation" of iron has been used to describe the introduction of the vanadium, nevertheless it was not available in sufficient quantities even for this. Years of exploration over all the world was carried out before it was found in commercial quantities in Peru.

Since that time we have seen all sorts of inoculated irons introduced. It has been said that without these our automobiles would cost at least five times what they now do. We are also told that had the cars of 1910 been built as strongly as those of to-day, their engines would not have been powerful enough to pull them. This is what the introduction of these new alloys, or inoculated steels, has done for us.

We have all noted the recent introduction of so-called stainless steel. This first appeared in cutlery. It was useful in the kitchen, as the knives retained their brightness instead of black-

ening in the usual way. It was too expensive for use where large quantities were necessary. Now it has been announced that one of our modern automobiles will be built almost entirely of this steel. It has been cheapened, and will be cheapened still more, until it will be used for all exposed steel work. It is a steel that contains a small amount of chromium.

By such methods we have steels resistant against acids, alkalies, salts, and even fatigue. These are inoculated with such materials as chromium, molybdenum, nickel, silicon, manganese, tungsten, etc. We can produce a steel of almost any desired properties now; the future will be concerned largely with cheapening these materials.

The x-ray studies of alloys are now beginning to tell us what happens when two or more metals are thus put together. In pure copper, for example, the atoms are piled together like spherical shot. Each atom touches twelve neighbors. As zinc is added, the atoms of zinc at first distribute themselves at random. As the amount increases, a new pattern will eventually be formed, in which each atom touches but eight neighbors. Next a very profound change takes place. As more zinc is added, the atoms rearrange themselves completely. The unit becomes twenty-seven times as large as before, and there are fifty-two atoms in it. This alloy is very hard

and brittle. There is an alloy of copper with tin, and one with aluminum, in which the same sort of change takes place. Studies such as these direct us along intelligent lines in our search for new alloys.

Chromium, the Newcomer

Ranking in importance with the production of new alloys, go the new developments in the plating of one metal upon another. Perhaps the underlying metal has nearly all the properties desired; yet it may not be free from corrosion where it is to be used, or it may not be sufficiently pleasing to the eye. Here is where plating solves the problem.

Of all the more recent developments in plating, that of chromium plating has proved the most valuable. Chromium is a particularly beautiful metal. It has a bright, platinum-like, satiny surface, and is free from corrosion from almost any known cause.

For many years our bright automobile parts were nickel plated. While this added to the beauty of the car when new, the nickel tarnished quickly, and, in the frequent polishings necessary, it sometimes wore off completely, exposing the metal underneath. Here lay the first major use of chromium; chromium plating on automobiles was the form in which it was introduced to the public. And this was but a short time ago.

Such plating is almost indestructible, and its bright surface never tarnishes and never needs polishing.

From this first use we find it branching out in all directions. Apartments are now being built in which all the metal fixtures are chromium-plated. Bathroom fixtures, door handles, and all other fixtures exposed to moisture, when plated with chromium, will retain their luster until the building is demolished. The built-in mirrors in such apartments are also of chromium. They are both beautiful and unbreakable.

And now we find this metal becoming even more aristocratic. It is already possible to buy chromium-plated tableware. This has all the beauty of silver, and never needs polishing. To wash it, it is only necessary to hold it under the hot-water faucet. It will not dry spotted as will silver. This makes the old-fashioned unsanitary dishcloth a thing of the past.

But chromium plate is not satisfied with even this conquest. It is now being sold extensively as jewelry. The beautiful necklace which appears to be of the finest platinum, may, in fact, be but a chromium-plated article. Yet it is beautiful and will neither tarnish itself nor blacken the skin. Jewelry to be beautiful no longer need be expensive.

But there are other developments in the field of plating. It is now possible to plate aluminum

on steel in the laboratory. If this can be made a commercially feasible project, we may soon expect to see our bridges made of shining aluminum strands. Aluminum, being much cheaper than chromium, will find many uses where the cost would not justify the use of the brighter metal.

The methods of plating are also applicable to other problems. Nearly all of our pure copper to-day is obtained in this manner. The copper is plated on an electrode by means of the same process used in ordinary plating. In the process the impurities fall to the bottom of the electrolytic tank.

Barium at $12,000,000 an Ounce

Did you know that there was actually in existence and in every-day use a material that is worth $12,000,000 an ounce? There is! This metal is no other than barium, a chemical element easy to obtain in large quantities cheaply. It is worth this enormous sum of money only when it is in the right place—on the filaments of vacuum tubes.

When a tungsten filament is heated it gives off electrons. This is a property which is necessary in vacuum-tube operation. It is the control of the flow of these electrons across the tube which makes the tube of value. Now, any way in which more electrons can be produced makes

the tube just so much more useful. Thus the problem is to get a plentiful supply of electrons from the filament at the lowest possible cost. Increasing the temperature of the filament by running more current through it is one way of getting more electrons, but this raises the cost for current and shortens the length of life of the tube. The other way is to coat the filament with barium oxid or some other material such as strontium or cæsium oxid. This, for some little-understood reason, has the ability greatly to increase the flow of electrons from the filament without the necessity of increasing the current through it. In fact, it will, with the same current, increase the electron flow about ten times.

Such coated filaments are in use in telephone repeater tubes and are working every day for telephone subscribers. It is in the saving in these that the value of $12,000,000 per ounce was estimated. Taking the cost of storage-battery power as thirty cents a kilowatt-hour, the power burned by such a tube during its life would cost $13.50. A clean tungsten filament would require ten times this. We may take the saving, then, as about $120 for the life of each tube. It requires but 0.0003 gram of barium for each tube to effect this saving. There is thus a saving of $400,000 per gram of barium used. In the Bell Telephone System alone there are 60,000 of

these tubes in use. This means that in the entire system there is slightly more than half an ounce of this material at work; yet it gives an annual saving to the company of $7,000,000. Hence the saving per ounce would be roughly $12,000,000. Thus we find that, while the metal barium is not classed among the rare metals, when put to this use it has an actual value which makes that of platinum, or of diamonds, appear but little more than that of the dust of the street.

In this connection there comes to mind another material which has likewise proved of immense value in the field of telephony. This is the magnetic alloy known as permalloy. It is an alloy of nickel and iron and has properties of magnetism much more desirable than those of pure iron. It is necessary, in long-distance telephoning, to have loading coils in the circuit—for clarity of transmission. These loading coils are wasteful of energy, however. At first they had iron cores, which were later replaced by powdered iron, each grain insulated electrically from every other. This resulted in a great saving. But the coils were still large and, in their electrical properties, wasteful. The new permalloy coils are very much smaller than the old iron cores; they perform the same function, and while their initial cost is much greater than the cost of the iron cores, the saving due to them is enormous.

So much is this so that these coils, resembling doughnuts in shape, have been called million-dollar doughnuts. Again we see the value of getting the right material in the right place.

II

NEW PRODUCTS FROM OLD MATERIALS

Money from Smoke

THOSE who think of coal merely as something to shovel into the furnace to produce heat are now a few years behind the march of progress. We have recently learned that there are a lot of things which can be made from coal. We have come to regard it as a raw product; merely the place from which to start in the manufacture of a number of articles of great commercial value. The fact that it will burn and produce heat is but one of its characteristics, and while this is, of course, important, we have learned that in this case, at least, we can have our cake and eat it too. In other words, we can have as much heat from our pound of coal as we have always had, and yet obtain from it a number of very useful materials besides. Perhaps, as you have watched the smoke curl up from a great stack, it may have occurred to you that something of value might be contained therein. If these have been your thoughts they are correct. In some poor grades of soft coal as much as forty per cent. of the weight of the coal may be in volatile products—products that become gaseous at low temperatures. To have a volatile con-

tent of as much as twenty or twenty-five per cent. is quite the usual thing. In such a case, for every hundred pounds of coal shoveled into the furnace twenty-five go up the stack. This does not take into account the black part of the smoke, which is carbon unconsumed because of poor combustion in the furnace—so much added waste. In the smoke which we have been sending out to pollute the air there are materials of value which, by suitable methods, can be recovered.

To recover these products of combustion requires, of course, suitable equipment. It would not be feasible to attempt to do this in every household nor even in every factory. It costs something to collect and purify these materials. In the past, methods of doing this have not been sufficiently economical to afford encouragement. Now new methods of low-temperature distillation have changed all that. It is now possible to drive off these by-products and to have the heat-producing part of the coal—coke—still left in its most desirable state.

In the past the coke which one purchased on the market was a by-product from the gas-house. Distributers of gas for local uses, after driving off all that was of value for their purpose, sold the resulting coke purely as a by-product. Now we are putting the shoe on the other foot. Large plants are springing up all

over the country in which the manufacture of coke as a smokeless fuel is the primary purpose. The volatile products are the by-products in this case. The result is a superior grade of coke to that with which we have been familiar.

In Germany this process has resulted, in some cases, in the burning of coal at the mine-mouth, piping the gas to the cities, and sending only the coke by rail. Gas from the Ruhr district now supplies Berlin, about five hundred miles distant, as well as intermediate towns and cities. Here is an advantage over the age-long dream of generating electricity at the mine-mouth, a system which requires a larger quantity of water than is usually available, for condensers. Already in the United States we have a similar project well on its way. A large corporation is supplying much of the northern part of New Jersey with by-product gas from the coke industry. Some of the pipe-lines in this case are seventy-five miles long.

The beehive ovens used in the manufacture of coke for the steel industry are also beginning to be harnessed. The long flames which one used to see flaring out at night from the many coke ovens in the vicinity of Pittsburgh will doubtless soon be things of the past. They are a spectacular but wasteful show.

Coal-Burning Motor-Cars

Along with the saving which we are beginning to effect in the recovery of waste products of coal combustion, we are also learning new ways to burn our fuel more economically. One of the newest of these ways is in the form of powder. The coal is first ground to a very fine dust, and by means of blowers is shot into the combustion chamber through nozles which resemble the nozles used in the burning of gas. The long blue flame, which results, also resembles closely the usual type of gas flame.

The advantage of burning coal in this way is at once obvious. In the first place, combustion of coal requires oxygen. Unless this gas comes in contact with each carbon particle, it cannot burn. In the powdered form each carbon speck has ready access to an oxygen supply on all sides, and the resultant combustion is almost perfect. It is also obvious that this method gives accurate control of combustion, so that the temperature of the furnace can be maintained within close limits. The fire can be started and stopped as quickly as would be the case with gas. On the other hand, one should not forget that the use of powdered coal must result in a sufficient saving to offset the original cost, and the cost of operating the pulverizing apparatus and the blowing equipment as well. Again, on the debit

side we must not overlook the constant danger of explosion. Dust, in almost any material, constitutes a dangerous hazard. An explosion is, after all, nothing more than rapid combustion, and coal in a powdered form will burn with explosive rapidity.

So far most of the powdered-coal installations have been on land where space was easily available for the powdering machines and blowers. Only recently has any attempt been made to utilize this fuel in other than stationary engines. This is because it has been necessary to powder it as it is used in order to avoid the danger of storage. Recently, however, a few ships have been equipped with powdered-coal installations, and, altho figures are not available to prove the point, it appears that they have been functioning satisfactorily. On ships the saving in the actual operation must be greater than on land in order to compensate for the space taken up by the auxiliary equipment.

Undoubtedly the most novel and interesting use to which powdered coal has been put is in the running of an internal-combustion engine. While it is not generally known, it is a fact that the first Diesel engine was designed to be operated on powdered fuel of this sort; but it proved impractical because the ash got into and injured the bearings. It is now claimed that this difficulty has been overcome. The result may be

a great change in the transportation of heavy materials in many places. Even now, in Africa, there are in use many steam wagons which use coal in the solid form as fuel to generate their power. In spite of the fact that it requires two men to operate these trucks, one to drive and one to operate the engine, they are economical because of the high cost of gasoline. Heavy internal-combustion engines which would burn powdered coal would be a great help. If they are sufficiently economical, they are likely to find a ready welcome in such countries as Germany. Most of the European countries are dependent upon Russia for gasoline and oil. Some, like Germany, have immense deposits of coal which they could thus turn to ready use. There would appear to be a real future for such an engine.

Perfume from the Coal Pile

On the other hand, chemists may make such an engine obsolete before it ever becomes a success. Already liquid fuel made from coal is for sale on the streets of Berlin. This synthetic gasoline is the result of the researches of the German chemist, Dr. Friedrich Bergius. The method is one of high temperatures and pressures. The coal is first ground into very small pieces and then mixed with a heavy oil to form a thick paste. This is put into a steel retort in an atmosphere of hydrogen and subjected to a

temperature of 800 degrees Fahrenheit and to a pressure of 3000 pounds per square inch. Under these conditions the hydrogen combines with the carbon of the coal to form gaseous, liquid, and solid materials similar to those from oil wells. The products have been described as follows:

> A ton of common bituminous coal will yield 300 pounds of gasoline, 400 pounds of heavier oils suitable for Diesel internal-combustion engines, 120 pounds of lubricating oils, and 160 pounds of fuel oils. As a rule about forty gallons of marketable gasoline can be expected from a ton of soft coal. The 120 pounds of lubricating oils are used in impregnating another batch of powdered coal. Among the products of this proccss is a quantity of carbolic acid or phenol, a familiar antiseptic and also a component of bakelite, used in the radio and phonograph.

In the past one of the difficulties in the way of the utilization of this process has been the cost of generating the hydrogen. Dr. Bergius obtains it from one of the gases, methane, which is a product of the reaction. This gas, when decomposed by steam, yields four times its own volume of hydrogen. Dr. Bergius has estimated that this process could be carried out in the United States at a cost of about $10 a ton.

In addition to these, many other products have been made from coal. We have substitutes for gasoline, petroleum, benzine, paraffin, and so on,

and even for such materials as wood alcohol. From the tar contained in the coal we are able to make a great variety of things, including such apparently unrelated articles as explosives, perfumes, dyes, and ingredients of medicines. The list is indeed a long one, and of itself would fill a page of this book. Any text-book of modern chemistry may be expected to contain such a list. Among the most recent items to be added to it are synthetic rubber and compressed gas for the operation of trucks.

It now appears that the coal industry is destined to play a large part in the development of agriculture. For many years our sole supply of nitrate for use in the manufacture of fertilizers came from the natural nitrate beds of Chile. Now, a number of methods have been developed for the synthetic manufacture of these nitrates, and one of the most important of these is the distillation of coal. Nitrates promise to be one of the most important coal by-products of the future.

Bringing the Rainbow to Earth

One of the greatest achievements of the chemist has been in the discovery of methods of making dyes. It is difficult for us to imagine, at this date, the hardships that men underwent in times gone by to bring the dye, indigo, by caravans from the East to the civilization of Europe. It

is difficult to imagine the dangers that were later undergone to carry cargoes of indigo around the Cape and up to Europe, a difficult if slightly safer route than that of the caravan. And later added to this trade came cochineal, an American product.

All this trade, romantic tho it may have been, is now a thing of the past. The chemist is able to make more and better dyes than nature ever made. Whereas Nature made but one good dye, indigo, which ranked in value with gold and the precious spices, man can now make dyes of any color cheaply and can even make indigo dye better than can Nature herself.

Something of the difficulty that confronted the chemist in this conquest is shown by the description of the problem which has been given by Dr. R. E. Rose. The problem, as Dr. Rose puts it, was this:

> To find how to make compounds that were reasonably accessible, that imparted useful hues to cotton, that could be applied by all the mechanical methods already known to the dyer, that were entirely insoluble in water, soap, and alkalies, that were chemically inert and therefore resistant to the action of light and oxidizing agents and even bleach, and that could be converted into water-soluble products by an easy cheap process, that would be colloidal when dissolved, and would possess colloidal dimensions in "solution" such that the dyes would ex-

haust or go on to the fiber from the bath, and would return, when on the fiber, to an insoluble material.

It is remarkable that any set of materials could ever fulfil such specifications.

For our dyes we are primarily indebted to three chemists. Perkin, an Englishman, set out to find quinine, but instead discovered the basic colors obtained from coal-tar. From this black, unpromising material have come the basic colors, mauve, safranine, magenta, methyl violet, crystal violet, malachite green, and auramine.

The second of the chemists, who have contributed fundamentally to our store of dyes, was Peter Griess. Experimenting on the action of nitrous acid on such amines as aniline, he uncovered the whole field of the so-called azo dyes. This gave us a whole new series of dyes of unusual properties in the dyeing of cloth.

The crowning touch to our knowledge of dyes was made by the work of René Bohn. He set out definitely to build up molecular structures resembling that of the best dye which Nature had produced, indigo. How could he produce molecules similar to those of indigo? How could he equal if not outdo Nature? His first success was the production of beta-amino anthraquinone fused with potassium hydroxid. This gave a blue which was a better color than indigo and dyed cotton faster than any dye previously known.

Chlorinating gave a greenish-blue color still more desirable. This was the first of the so-called vat colors. As the result of the work of Bohn, and that of others who entered this interesting field of discovery, the vat colors include to-day all colors from the greenest yellows through pinks, blues, greens, and black. The chemist has been able to outdo Nature completely. He has brought the rainbow to earth.

Is Glass a Gift of Nature?

We have become so used to glass that it does not strike us particularly as a blessing. We think of glass as something handed to us by Nature in much the same way as she has supplied us with water and air. This is far from the case. Glass is a man-made product. It is wrested from Nature by the cleverness of chemists. True, those who first produced glass could hardly be called chemists, as we define the word to-day. Nevertheless, they made the glass by methods which certainly must be called applied chemistry, unless, of course, we are to regard the religious ceremonies which accompanied the manufacture in early times as a necessary part of the process.

As a matter of fact, we may even criticize our chemists of to-day and justly accuse them of adding but little to the process given to us by the ancients. The early glass-makers probably did a better job than they themselves supposed.

True, they used laborious methods; they did not have pure materials, nor did they know how to purify them. They did not have high temperatures available, and this marred their success somewhat. Nevertheless, we have learned and are still learning much about the manufacture of glass from the empirical methods which they gave to us.

If we examine into their records we see that they varied from modern practise only in the lack of modern equipment and in the religious ceremonies attendant upon the manufacture. In the British Museum some tablets taken from the Temple of Nabu describe glass-making in Assyria in the seventh century B. C. Let us consider first the translation of these by R. Campbell Thompson, and then later let us consider some comments on these directions by the noted glass-chemist, Mr. F. C. Flint. The translation reads as follows:

THE MAKING OF ASSYRIAN GLASS

Translations of
R. Campbell Thompson

A. The preparation of the furnace.

(L. 1). When thou settest out the ground-plan of a furnace for "minerals" thou shalt seek out a favorable day in a fortunate month, and thou shalt set out the ground-plan of the furnace. While they are making the furnace thou shalt watch them and work thyself, in the house of the

furnace: Thou shalt bring in embroys (born before their time) . . . another, a stranger, shall not enter, nor shall one that is unclean tread before them: the day when thou puttest down the "mineral" into the furnace thou shalt make a sacrifice before the embroys: thou shalt set a censer of pine incense, thou shalt pour kurunnabbr. before them . . .

The wood which thou shalt burn underneath the furnace shall be styrax, thick, decorticated billets which have not lain exposed in bundles but have been kept in leather coverings, cut in the month Ab. This wood shall go underneath thy furnace.

B. The making of the frit.

(L. 13). If clear (ibbu) blue glass is for thee to make, thou shalt crush separately:

10 mana of sand (equal to about ten pounds); 15 mana of alkali ash (equal to about fifteen pounds); 1 ⅔ mana of styrax gum (equal to about ¼ pound).

Thou shalt mix them together and put them down in the furnace whereof the floor of the apertures is cold, and settle them evenly between the apertures. Thou shalt keep a good, smokeless fire burning until the "metal" is at white heat: then thou shalt take it down into the furnace which has been let grow cold: then thou shalt keep a good smokeless fire burning until it liquefies: then thou shalt pour it on burnt brick.

Of this and its continuation Mr. Flint says:

In this tablet mention is made of the use of gold, antimony and tin oxid for red glass. These are still used, tho lately in America we have added selenium and uranium to the list. They

also mention the use of ferric oxid, arsenic, chalk, saltpeter, alkali (salicornia), copper, manganese, sulphids, mercury and sand.

In other words, in that ancient day they were using nearly as many ingredients as we are to-day. Also, the raw materials were probably impure. That is why they found it necessary to use so much soda ash. Modern batches to-day would call for 1,000 mana of sand and only about 400 mana of soda ash and 200 mana of limestone. Probably the ash introduced considerable sand of its own accord. It must have introduced a little lime also, as they did not use very much.

On the whole, however, the formulas which they used then were remarkably similar to the formulas we use now. What we have learned about glass-making has been limited to refinements in the raw materials, sources of heat, and speed. They used pot furnaces, which are still used in Europe and parts of the United States. The bulk of the glass now is made in large furnaces.

The New Structural Material—Glass

It is clear from this that the fundamentals of glass-making are far from new. True, we have advanced far beyond the early artizans, both in quality of material and in economies of labor. In early civilization, clear glass was a rarity. Glass was used mainly for purposes of decoration. It was accordingly, for the most part, either colored or opaque. We have added tremendously to the uses of glass. Our electric-light bulbs, our radio tubes, our use of glass bottles,

glass used as electrical insulation, all add greatly to the demand. One need not think long to bring to mind hundreds of uses which make glass essential to our civilization. Scores of industries owe their being to glass.

Under these conditions it is to be expected that the glass-maker will leave no stone unturned to improve his product. Pure materials go a long way toward this improvement. Consequently he searches the earth from end to end for the exact ingredients which he requires. He wants them in their purest forms. Neither is he satisfied in merely obtaining a result which is desirable. He wants to know exactly how the result was obtained. All this is a job for the chemist.

Glass is about three-fourths sand. It is necessary that the sand be the purest obtainable. In this country the chief sources are in West Virginia and Illinois. We import some from France and Belgium. The sand is washed many times before it is put into the melting pot to remove any impurity. But sand alone could not be melted except under enormously high temperatures. When soda and lime are added, however, a melting point of 2600 degrees Fahrenheit results. This is a white heat.

Such a process would, of course, result in making glass. But it would be glass such as you would not be willing to accept for many of the

purposes for which glass is ordinarily used. It would be a dirty green product. It needs many things to make it acceptable. Antimony, or perhaps niter, must be added to give glass the brilliancy which we associate with it. But this still does not give us the finished product. Mixed in with the materials used there is usually some iron. It would be much too costly to remove the small amount of iron present by chemical methods. We must, instead, neutralize its effect. The greenish cast that is the result of this iron is accordingly removed by the introduction of cobalt. The action of the cobalt has been described by Mr. Flint—to whom the author is indebted for much of this information—as resembling the action of bluing on clothes. It requires but one part of cobalt in 400,000 of glass to take out the green color. The addition of selenium also helps in this neutralization process.

The addition of larger quantities of cobalt than are needed to neutralize the green, results in a blue glass, which will become dark blue when one part in 2000 is used. The addition of selenium gives the glass an attractive pink color, which is much used in tableware. Large quantities of selenium give a deep red glass suitable for signals. Copper or chromium added to glass produces a bluish-green material. Uranium makes yellow glass. Cryolite and fluorspar are used in the manufacture of the white or opal

glass. The heat-resisting glass, which has come into comparatively recent use, is the result of the introduction of boron into the glass. Only very recently the introduction of other materials, as yet not generally known, has given us glass transparent to the ultra-violet rays, and also non-shatterable glass. Chemists are spending a great deal of time in the improving of these glasses.

In the manufacture of various articles from glass there are but two fundamental processes. Either the hot glass is pressed into molds, much as iron castings are made, or else it is collected into globules on the ends of hollow pipes and blown into shape. Both of these processes were hand jobs until recently. Now glass-working machinery has almost entirely replaced hand labor. One can almost say that only in artistic glassware is hand labor now used. Even in such a comparatively complicated process as that used in the manufacture of radio tubes one finds the work done by machines. Placed on large slowly rotating tables, the tubes pass from one set of flames to another, until each has had sealed into it the internal electrodes, has been properly shaped, has had the air exhausted from inside by powerful vacuum pumps, and has finally been sealed off, complete except for fastening on the base. This is but typical of the modern methods of glass handling. Similar ex-

amples could be drawn from almost any process in which glass is made into useful articles.

Such, in brief, have been the methods which have surrounded us with glass, until the idea of living in glass houses is no longer a matter of imagination. In some factories and office buildings, as we all know, the major portion of the exterior shell is glass; but the time may not be far off when the walls themselves will be built of opaque glass blocks. Glass is being developed as a structural material, and such blocks could be manufactured now if the cost were brought low enough to compete with other building materials such as stone, brick, and cement. It is small wonder that we take our abundant glass for granted, almost like water and air. It is well to recall occasionally, however, that even glass windows were once a luxury.

A Chemical Dr. Jekyll and Mr. Hyde

To include alcohol along with such industrial materials as have been described may seem a bit surprizing; it does not appear to belong with such admittedly important materials as coal, dyes, and glass. Just because it seems out of place in such company, however, it is all the more interesting to find it here. Industrially it is an exceptionally important material. We see Alcohol on the streets late at night, and conclude that he is a rowdy fellow. We do not see him

the next day when he is hard at work turning out useful products which even the most temperate of us will be willing enough to use. It is to this hard-working side of the chemical Dr. Jekyll and Mr. Hyde that your attention is called. Before describing its uses, however, the author is tempted to quote some amusing figures given by Dr. R. E. Rose. He writes:

> The chemist is not much interested, as a member of his profession, in the advantages or disadvantages of the control of alcohol for drinking purposes. It amuses him to think of the Eighteenth Amendment in terms of molecules. Perhaps it would be terrifying to a rabid Prohibitionist to know that a liquor containing one million times one million times one million times 16,000 molecules of alcohol in one teaspoonful would still be entirely legal, so that after all the human body can stand quite a number of alcohol molecules.

Perhaps this is but one of the little jokes of our Mr. Hyde.

But, quite apart from the importance of alcohol in social-welfare problems, it is of great importance industrially. In fact, in one particular it can be said to be next in importance to water. Water owes its chemical importance to its great ability as a solvent. More useful solids can be dissolved in water than in any other liquid. Second to water comes alcohol. It will dissolve many things which can be dissolved by water,

and many more besides which water will not dissolve. Herein lies its chief value.

As an outstanding example of the industrial value of alcohol let us consider our modern enduring lacquers. We all know that to-day our automobiles are sprayed with a lacquer that is many times as resistant to weather as was the paint used but a few years ago. Not only is it more durable, but it is a large factor in the reduction of cost of manufacture. Instead of requiring many coats of paint and varnish, a great deal of rubbing down to get a smooth surface, and two or three weeks' drying period, the bodies are sprayed and are ready for use in a matter of hours as compared to days by the old process. This conserves space, saves labor, eliminates storage cost, and frees capital. We must thank alcohol. It can be converted into ethyl acetate and ethyl butyrate, which are used to dissolve the nitrocellulose which is the base of these new lacquers. This is but one of the more striking and recent uses of alcohol in commerce. There are many others, as any chemist can tell you.

Perhaps the analogy with Dr. Jekyll will be even more justifiable if another use of alcohol is cited. Beside alcohol, Dr. Jekyll, be he the best doctor the world affords, must indeed take a very secondary place. But be not alarmed; this praise has nothing to do with alcohol as a

beverage. It relates to something quite different. Ether, that anesthetic with which so many of us have become familiar in our experience on the operating table, is made directly from alcohol. If you take two atoms of hydrogen and one of oxygen from two molecules of alcohol, you have left a molecule of ether. With the hydrogen and oxygen which you have removed you could make a molecule of water. Was the praise justified? Has not ether prevented more pain, made more operations possible, saved more lives, than the most noted of the world's physicians?

But we do not as yet know all that alcohol can do for us as a chemical. We have already—in Part I—discussed the use of ethylene gas for ripening fruits and for shortening the period of dormancy of potatoes. This promises important developments in the field of agriculture. Ethylene is another beneficent agent. It is made by pulling a molecule of water from a single molecule of alcohol.

Alcohol is not always a reprobate. It behooves us, then, in curbing his merry-making, to be sure that we at the same time do not prohibit him from doing useful work.

III

MODERN MIRACLES

Heavy Jobs for Bacteria and for Molds

THE enormous amount of research that is being done in the industries to-day has resulted in an entirely new outlook on the part of the business world. No one knows where his business will be to-morrow. One of the last industries to think of research was the cotton industry. Yet almost overnight the cotton industry finds itself in competition with artificial silk. If it had taken the proper course, it should, itself, have been the first in this new field. Now it finds itself in a competition for which it is far from well equipped. While the coal industry was spending most of its energies in internal difficulties, it suddenly awoke to find its place being taken by the oil industry. Now, awakened, it is carrying on research to find new outlets for its raw material. In the meantime it has suffered severely. It felt as safe from competition as does the milk industry to-day. Yet who can say that we may not have synthetic milk?

No industry, to-day, is safe without research. No business is free from competition, and the competition does not stay within a single industry. The customer may choose between a radio,

a camera, or a phonograph. He will buy the one which is the farthest along in its development. If the sound produced from the radio is more true to life than the pictures produced by the camera, he will probably buy the radio. Competition now knows no limit.

The fact that no one can tell in which direction research will develop has been a great annoyance to the business man. He feels that something is wrong in a case of this kind. If his chemists set out to make synthetic rubber, he expects them to make synthetic rubber. This they may not do. If they take advantage of lucky breaks they may turn out something quite different. It was in just this way that our modern lacquers came into existence.

To make synthetic rubber cheap, butyl alcohol was necessary. It was found that certain bacteria would ferment starch and produce butyl alcohol and acetone. Acetone was needed to make smokeless powder during the war, and the bacterial method of manufacture was used. Great tanks of the butyl alcohol were stored, as no one had a use for it. Twice as much butyl alcohol as acetone is produced by this method.

After the war great quantities of nitrocellulose, used in making explosives, were available, and butyl acetate was a good solvent for this. Accordingly the butyl alcohol was made into butyl acetate and used to dissolve the nitro-

cellulose. Thus a new kind of lacquer came into being as the result, initially, of the search for methods of making artificial rubber. The probability is that this lacquer is of more value to the automotive industry than would have been the synthetic rubber which was the original quest. Such things make it impossible to predict where research will lead to. It is the common story of research.

The use of bacteria to assist in chemical reactions is becoming of increasing importance. The same thing can also be said of the use of molds. We normally think of molds as being like that furry substance which spreads over bread left too long in the bread-box; but this is only one member of the great mold family. These molds are often expert chemical technicians. They can perform, quite simply, chemical jobs that would require the erection of great plants extending over acres if we were to do them by purely chemical methods. "Microbiological chemistry is the chemistry of the future," say Dr. Horace T. Herrick and Mr. Orville E. May, of the United States Bureau of Chemistry and Soils, continuing:

> Most of nature's growth processes are catalytic, by the action of enzymes. When the chemist or engineer attempts to duplicate them, he takes acres of ground, tons of machinery, the productive labor of hundreds of men, to imitate

what nature has done in the stem of a plant or the leaf of the tree, and frequently he makes a bad job of it.

Tartaric acid is formed in the grape from the same materials from which the dextrose also found there is produced, and tartaric acid can also be manufactured from dextrose by a biochemical reaction. There is a mold somewhere that will do the same work—the task is to find it and put it to work in the conditions under which it will work most happily. For molds are temperamental, but so is the human laborer, and molds have their advantages. They do not sleep on the job, they work twenty-four-hour shifts, there is no strike, no turnover. All they need is infinitesimal quantities of food, a comfortable home in a temperate climate, and protection from their enemies.

Thus we see that there is more ahead for the chemist than one would at first suppose. It is not enough that he find uses for idle elements; it is not enough that he give us constantly new alloys, or that he make merely a better product; in the competition for the customer's money he must strive for an ideal product. But, after all this, he must begin to study bacteria and molds in the hope that he may find one that will do a job, perhaps not even guessed at yet, better than he can do it by purely chemical means. He must put bacteria to work to make lacquer for our cars. He must put molds to work making coloring matters, sugars, starch, fats, urea, and alco-

hols. He must put them to work making citric acid from dextrose, as difficult a chemical task as can be found. Such is the occupation of our modern chemist.

Peacetime Dividends from a War Service

Nearly everyone is familiar with the work that was done by the Chemical Warfare Service during the World War. We all know how, by the development of protective gas-masks, they were able to save the troops from the first gas-attacks, and how later they were successful in the preparation of new gases for the offensive. Even the names of the gases used in the war are now fairly well known to all. What have the chemists been doing in the meantime?

Since the war they have been carrying on incessant research. They have been attempting to anticipate everything that a future enemy might do; every new gas which he might introduce. It will not do to wait until the enemy appears with his new gas. We must be able to meet any and all attacks which might come. Thus there are those in the Chemical Warfare Service who are constantly seeking new poisonous gases, and there are those, on the other hand, who are constantly finding ways of protecting against the new devices developed by the offensive section.

Most of the information concerning the real successes of this Service, of course, is not avail-

able to the public. If it were, it would soon reach potential enemies, and, in the event of war, all our secrets would be available to them. Some things, however, can be told. For example, the Service has perfected a new type of gas-mask, much lighter than the one used in the last war, which gives greater protection and does not muffle the voice to such an extent as the old. This is a great advantage to those who must give oral commands. It has also been announced that an improved chemical mortar has been developed which will give from two to five times the distribution of warfare chemicals that the old mortar would give. Methods of laying down smoke-screens, other than by these mortars, has likewise been improved. Tanks can now be equipped with smoke-producing guns, and a single airplane can lay down a smoke-screen 8000 feet long while flying at a speed of from 150 to 250 miles per hour.

Perhaps the success of the Chemical Warfare Service can best be measured by its peacetime service outside of its actual field. Many of its discoveries have been of use in every-day life, and these have been turned over to the public. These by-products have been important and numerous, and, realizing that they are only by-products, we may get some idea of what the chemists must be accomplishing on their major problem.

Naturally, their work being largely with poisons and protection against them, their contributions have been in this field. One of these has been the development of a peacetime gas-mask for protection against carbon monoxid. This gas is present wherever there has been incomplete combustion. It is one of the things feared by firemen. Being odorless, it is never detected through one's natural senses by the individual exposed to it. He must have some chemical means of detecting its presence. In the past, to enter with any safety a building containing quantities of carbon monoxid, it was necessary to use a mask connected by a long tube to an outside source of air. This was seldom practical. Now a light mask containing a new substance, hopcalite, offers complete protection. It turns the carbon monoxid into carbon dioxid. Hopcalite is used also to detect small quantities of carbon monoxid in the Holland Tunnel between New York and New Jersey. While more than adequate ventilation is provided for this tunnel, through which thousands of automobiles stream hourly, no chances can be taken. Should the amount of carbon dioxid for a moment run to a dangerous amount, a warning is at once given by the chemical.

The Chemical Warfare Service is also making good use of offensive poison knowledge. Being experts in this field, its members have been called

upon to assist in finding remedies for all kinds of pests. These include such diverse things as mosquitoes, rats, rattlesnakes, prairie dogs, hair-seals, fleas, bedbugs, moths, bats, and black-birds. Their most notable contributions have been in the control of the boll-weevil, the marine borer, and barnacles.

For some time the only poison used successfully against the boll-weevil was calcium arsenate. The Chemical Warfare Service has developed two other insecticides which are quite as effective as this material and less costly. The marine borer does much damage to piling along the water-front. Organic compounds of mercury, arsenic, and copper have been found effective in the case of this pest. Test blocks submerged for three years have shown no signs of attack by the marine borer. For protection against the various forms of marine growth, common on the bottoms of ships, the Chemical Warfare Service has developed a paint for ship bottoms which promises success. It is being tested on several ships of the navy.

All ships entering the United States must be fumigated for the purpose of killing rats and fleas, which might bring in dangerous diseases. For this purpose the deadly gas, hydrocyanic acid, has been used. But many human beings have been killed by this fumigant, and it has now been replaced by tear-gas (cyanogen chlo-

rid) mixed with hydrocyanic acid. Long before the mixture becomes dangerous to humans they are warned by the effect of the tear-gas on the eyes.

Such, in brief, is the work of the Chemical Warfare Service in the United States, and there is much the same story connected with the corresponding units in other countries. They are paying peacetime dividends.

Clothes from the Chemists' Test-Tubes

The earliest clothes worn by man were direct products of the hunt. He was clothed in the skin of whatever kind of animal happened across his path—when he was able to kill it. Later he began to use the hair and wool of animals to make his clothing. This was a great improvement. The use of plant products, such as cotton and flax, came as a comparatively recent development. Now comes the chemical age. Our next clothes will come out of the laboratory. Only in the last century have our cotton products exceeded those of wool in quantity. Now we find artificial silk climbing up the scale. Already it has passed natural silk, and the list now stands: cotton, wool, artificial silk, and silk. This shows which way the wind blows. In the end it seems reasonable to suppose that all the cotton itself will be made into artificial silk, because of its greater beauty.

On the other hand, since it requires the best kind of cotton to make lacquers, it may be that this will raise the price of the cotton to a level such that the artificial silk industry will have to look elsewhere for its cellulose. Perhaps it may find it in pulp-wood, but here it will have to compete with the news-print industry. In the end the competition for the natural cellulose molecule may make it economically feasible to build up this molecule synthetically, provided some one can find a way of doing it. It would seem that nature could do this much more cheaply than we can, however, and that we are more likely to find the solution in other ways. Perhaps we might develop a hardy cotton plant which can be grown farther north. Or perhaps we might find a hardy substitute plant. Already a weed which is found in Guiana, and which produces a cotton substitute, has been cultivated in England. This is but the beginning of a long series of plant experiments which may completely revolutionize the clothing industry.

Then, too, the chemist may soon be expected to gain sufficient courage to launch out in search of entirely new clothing products. Up to the present he has confined himself to making substitutes. He has made artificial silk, he has made artificial leather, and so on. There is no reason why new plants or new products should be imitations of anything. It is possible that new

plants, with fibers suitable for wholly new kinds of cloth, might be found. It is equally likely that the chemist might produce a wholly new material unlike anything that we have ever seen before, with entirely new and desirable properties.

In the manufacture of dyes we first began by an attempt to imitate Nature. Then we were able completely to outdo her. In the same way in the manufacture of cloth, leather, and so on, now that we have shown we can imitate Nature, let us see if we cannot go far beyond the natural products which we have found it convenient to use in the making of clothing. This we are almost certain to be able to do. We are already entering this new era, and we may confidently look forward to many developments in the next few years. Having reached both the animal and plant stage, and having seen the latter begin to wane, we may now look forward to seeing our clothes come out of the chemist's test-tube.

Beefsteaks from the Air

"If it had not been for the invention—and a great invention it was—of the production of synthetic fertilizers," to quote Sir Alfred Mond, "I do not hesitate to say that the world to-day would be suffering from a famine, the population of the world would have declined, and any future increases of population would have become practically impossible." There, in brief,

you have a statement of the importance of the synthetic fertilizer industry which the chemist has created. Let us see how he has gone about it.

For the promotion of plant growth it is absolutely essential that there be nitrogen in the soil. This goes to form the nitrates used by the plant. The plants which are eaten by animals provide, for them, the nitrate which they require. When either the plant or animal dies, the proteins which have been formed through these nitrates decompose and, in part, form ammonia. Through the action of bacterial and of chemical elements, which are present in the soil, this ammonia is again reduced to soluble salts, which are again taken up by the plants; or it may be reduced to nitrogen, which escapes into the air directly. Some nitrogen will occasionally return directly to the soil through the action of a lightning storm. It is this factor in an electric storm which makes it of so much more value to the plant than merely watering with the garden hose. This process by which the nitrogen circulates from one form to another is known as the nitrogen cycle.

It would appear that this circulation would give us nothing to worry about. The nitrogen circulates from the soil to plant or animal and back to the soil again, or from the soil to the air and back again. This would be all right if there were no leaks in the cycle. But such leaks

exist. Great quantities of useful nitrates are sometimes washed out of the soil. Sometimes they are deposited in great nitrate beds, as in Chile. But this is not always the case. They are more often washed out to sea, where they cannot be recovered. Another leak in the cycle is evidenced by the great guano beds, which have, however, now been used as a source of fertilizer. At the present moment our great cities, which send their garbage out to sea, represent another serious leak in the nitrogen cycle. True, some of this is returned to the soil in the form of fish-fertilizer, but not enough to balance the loss.

Confronted with this situation it has become necessary for man to tap the air itself as a source of cheap nitrates. The process is known as nitrogen fixation. The first method by which this was carried out was the so-called *electric-arc process*. This was the method of fixation most closely resembling that of nature—fixation by passing air through a powerful electric arc. Such a process is economical only where power is very cheap. The first plant of this kind was erected at Niagara in 1902. Even here it proved too costly, and the plant was closed in 1904. At the present time but two plants, both in Sweden, use this process.

If we can produce ammonia we shall have no worry about reducing this to fertilizer. Thus all fixation methods concern themselves with the

manufacture of ammonia. Now, ammonia is a chemical substance consisting of three parts hydrogen and one part nitrogen. Thus if we can catch three molecules of hydrogen and combine them with one of nitrogen our problem is solved. Processes of fixation, then, are methods of first getting the gases and then combining them.

Hydrogen can be obtained by passing an electric current through water. This breaks the water up into hydrogen and oxygen. Nitrogen can be obtained by liquefying air and allowing the nitrogen to boil off. The nitrogen vaporizes at a lower temperature than does the oxygen. Both in the production of the hydrogen and in that of the nitrogen we have oxygen left. This by-product may be used in oxyacetylene welding and for various other purposes. These methods are, on the whole, expensive and in general are not used unless a ready market exists for the by-product.

Another method of obtaining hydrogen is by passing steam over white-hot fuel-beds. The oxygen is burned out, leaving a mixture of gases which contain about fifty per cent. hydrogen. Tar is precipitated out of this mixture electrically, and the gases are frozen out. This provides many by-products. The needed nitrogen is then produced by burning some of the hydrogen already obtained in air. The oxygen is thus consumed and nitrogen remains. Now the problem

is to combine the nitrogen and hydrogen into ammonia.

Up to this point the materials which are to form the ammonia have been pretty roughly handled. They may have been subjected to a temperature of 300 degrees below zero Fahrenheit, they may have been passed through arcs of 50,000 volts. Now we take the right proportions of hydrogen and nitrogen and subject them to presures of 15,000 pounds per square inch, and at the same time we raise the temperature to 1000 degrees and pass them over a catalyst. The catalyst is another chemical which is merely an agent to promote the reaction. It is not itself consumed in the process. It might be called a chemical slave-driver.

This treatment results in the formation of some ammonia. This is drawn off and the gas circulated over the catalyst again. The process goes on continuously, more gas being occasionally introduced. In this way our fertilizer is produced; it feeds our plants, upon these cattle feed, and so in effect we bring to our tables beef-steaks from the air.

How long can this go on without influencing the supply of air above us? One manufacturer says: "The plant operating at its present capacity of twenty-five tons a day could be supplied with its nitrogen from air over the plant site only for a period of approximately seventy-five

years before it would be necessary to call upon the air over neighboring property." It should be remembered that this time will be greatly lengthened by the return of much of the nitrogen, put into the soil, back to the air again. Also many of the nitrogen leaks are being gradually stopped up. The scientific treatment of garbage is gradually being developed to a point where it may be expected shortly to restore much of its nitrogen to the soil for use. We may be sure that the time will never come when the fertility of the soil cannot be restored because of a lack of nitrogen. None of it leaves the earth, and so long as this is so it can be recovered. Chemists are constantly making it easier for us to recover it. So much is this the case that the synthetically-produced nitrogen now controls the price as against the cost of marketing nitrates from the natural nitrate beds of Chile, which for so many years held a monopoly.

This marks a great conquest for the industrial research chemist. He refuses to be defeated by even such a formidable thing as a monopoly of materials. In such a fashion does he defeat even those limitations set by Nature on the saturation-population of this earth of ours. Future historians must look back upon this development as one of the most important of all times. Food is man's prime necessity.

IV

THE CELLULOSE AGE

Clothes Made of Sunlight

WHAT next is to be our great industrial move? We can unquestionably refer to the age just past as the steel age. To-day we can point out among our citizens the giants of the steel industry, the men who have made steel the important industrial commodity that it is. They still walk among us. When these men are gone there will be no more towering figures in steel. There will be none to replace them as pioneers in this field. Those to follow will be but tillers in a field already broken.

But we are not a people given to ancestor-worship. There is still much to be done, if not in steel. We are now entering the age of cellulose. Here we may expect to find a new race of giants. The cellulose molecule is the structural basis of the plant kingdom. We know very little about this important molecule. As yet no chemist can give you its structural formula. Cellulose cannot as yet be built up synthetically. It can be made only in the industrial laboratory that is locked up in the tiny cells of plants. It is the product of sunshine. Without sunshine the plant can no more make cellulose than can we. The

more we utilize this mysterious material, cellulose, the more we are using this free sunshine which comes to us every day. In that respect we might say that we are entering the sun age.

In the past there have been three major industries dependent upon the cellulose molecule. These have been the lumber industry, the paper industry, and the cotton industry. Up until recently we knew of no other way to use the cellulose molecule on a large scale than through these industries or others which hinged directly upon them. Now we are constantly finding on the market new products which we recognize at once as coming from this source.

Let us consider for a moment some of the more outstanding of these. Artificial silk is a cellulose product. The artificial silk industry is but eight years old in America, and yet the production for 1929 has been estimated as 140,000,000 pounds for this country alone. Our shops are filled with beautiful, and yet inexpensive, clothes made of this material. The shop-girl of to-day can dress in a fashion that would have been the envy of queens had she appeared so arrayed a century ago. And yet this material is made from the same base as is cotton. It is cotton with the drabness removed. Or it may be made from trees. In this case it has the same origin as paper. Our girls may be said to be dressed in a material not far removed from paper. And yet

it is very different from any other wood product.

If we were to follow this beautifully-dressed girl about we should find her enjoying many other cellulose products. Perhaps the artificial ivory handle of her hair-brush, perhaps the little boxes on her dressing-table, are also made from cellulose. If we enquire too closely into the apparently beautiful leather seat on her sport roadster we are almost certain to find that this too is made from cellulose. The lacquer on her car, perhaps in the several shades which make her roadster the envy of all her friends, is also a cellulose product. And as she takes some colored motion-pictures of her favorite football or polo hero the images are recording on a film which has cellulose as its base. The thin transparent paper, cellophane, which wraps the gift-box of candy, glasslike in its transparency, is also the gift of the sun through the cellulose molecule.

We have not come to the end of new cellulose products. Here we have mentioned some of them. There are many more. And there are still more to come, of which as yet we have not even dreamed. Dr. Charles Holmes Herty, past president of the American Chemical Society, has said:

> What may we not expect in the utilization of cellulose once we get a clear, accurate picture of just how that molecule is made up? I do not hesitate to say that we have a right to expect

an indefinite number of new industries that no chemist dreams of to-day. We are earnestly looking all the time for means of increasing our national wealth. To-day the greatest freely-given wealth is sunlight, the energy of the sun. The question that all rational people are asking themselves is: are we making the wisest use of that great daily source of new riches, which costs us nothing to obtain?

Farming Chemicals

As has already been said, cellulose forms the structural basis of all plant life. It is formed by the synthesis of carbon dioxid, breathed in by the plant, through the action of sunlight. It is present in all plant life, and it should therefore be possible, theoretically, to obtain cellulose from any plant. Any roadside weed might be expected to yield artificial silk. The material thus appears to be very easy to get. But this is a false impression. While it is present in all plant life, it is frequently so bound up with other carbohydrates that the process of separation is either as yet unknown or perhaps so expensive that it is not commercially feasible.

In the past the major source of the cellulose, used in the artificial silk industry, alpha cellulose, was cotton. More recently wood pulp has grown in favor, so that now we find much artificial silk on the market derived from this source. In the meantime the chemists are examining

every possible source for cheap cellulose. The competition is extremely keen, and developments are so rapid that any manufacturer unwilling to carry on research will soon find himself far behind in the race. Among the many materials which have been investigated and found promising are flax, jute, china grass, hemp, sea grasses, coconut fiber, hop, broom, willow, banana, rice hulls, peanut shells, and even tobacco stems. Some day, therefore, one may puff on a cigaret while clothed in tobacco stems.

Perhaps of all the sources that have been investigated none is more important than the cornstalk. This is not because it promises to outstrip or replace all or any of the sources that have already been established, but rather because it offers the hope of increasing the farmer's income without the addition of new machinery or farm labor. It also may be said for the first time to bring the farmer into the chemical industry as a producer of raw materials. Regardless of how many slogans may be invented for the purpose of urging us to eat more beef, or to eat an apple a day, we can eat only so much. The farmer cannot, by this method, increase the demand for his products beyond our actual needs. He can only make us more discriminating. On the other hand, we seem to be far from the saturation point for new luxuries which the farm might produce in the form of

raw chemical materials. Thus the introduction of the farmer into the field of artificial silk, through the medium of cornstalks, may result in an entirely new outlook on his part. We may yet have a purely chemical farm.

Already there is operating in America a large corporation formed for the purpose of making artificial silk from cornstalks. This concern has studied methods of harvesting the stalks and of bringing them to the factory by means which are sufficiently economical to permit them to compete with manufacturers using other sources of raw material. While no definite reports are at hand, it appears that the venture is a success.

By-products of the Farm

Many things besides artificial silk can be made from cornstalks. The cellulose obtained might be put to many other uses such as have already been mentioned—making lacquer, leather, etc. Also we can obtain from the cornstalks certain sugars by treating them chemically. Dry distillation will produce certain gases, acids, tar, and charcoal. The stalks may be fermented to produce alcohol, acetone, and so on. There is an almost unlimited number of things which can be made from this waste material. The only question is whether or not it can be done on a basis to compete with other methods of making the same articles.

The answer to this is perhaps that it can be done where much of the material is available inside a reasonable area. In the eastern part of the United States cornstalks are used for animal food and are therefore valuable. In the West there is grown far more corn than can be used for this purpose. It is grown primarily for the grain. The useful part of the corn plant in these areas constitutes less than half the weight of the plant. The remainder has some value as fertilizer, when plowed under, but it is generally agreed among farm experts that this value is very small. If industry can use the stalks, therefore, it may have them for little more than the cost of harvesting. A price of five dollars an acre for them, as they stand in the field, however, is so much more yield to the farmer than he would normally get, and in addition the clearing away of the stalks means less risk the next year from the corn-borer.

Study of the problem by farm and chemical experts of the United States Bureau of Standards has led to the conclusion that the most promising use of these stalks at present is in the manufacture of wall-board. The stalks are shredded, treated chemically, and finally pressed out into boards. For the purpose of making a complete survey of the feasibility of establishing such an industry the Bureau, in cooperation with the Iowa State College, has established a

model factory for making wall-board. It appears at present that this can be manufactured in competition with other wall-boards now on the market. The project is being encouraged for the purpose of farm relief.

It is interesting to note that such a project may contribute to farm relief in another direction. The insulating value of straw against heat-transfer has long been known. Primitive houses and barns were long ago built with loose corn-stalks or other similar material piled upon the roof. The board made from cornstalks has also a high insulation value for heat. Because of this, barns and poultry houses lined with such material have greater warmth than unlined buildings, with the result that the animals thrive and yield an increased product. It has been found that the egg production of hens is greatly increased in this way, as is also the production of milk from cows which are warmly housed. The farmer benefits in more than one direction.

The experiments by the Bureau of Standards and Iowa State College have also included the manufacture of paper from cornstalks. The success in this line has been sufficient to induce some men to go into the business, and cornstalk paper is available in the market. Dr. Henry G. Knight, of the Department of Agriculture, has said:

Cornstalk-paper pulp is being produced, and during the last year at least one book and editions of several newspapers and at least two farm papers were printed on paper containing a high percentage of cornstalk pulp. Experiments carried on in the Bureau of Chemistry and Soils and also by Dr. Sweeney at the Iowa State College, Ames, Iowa, have shown conclusively that cornstalk pulp makes satisfactory wall-paper.

Straw, in much the same way as cornstalk, is becoming a commercial product. From this, also, commercial wall-board has been made successfully. Much of what has already been written concerning the increasing importance of the cornstalk applies directly to straw as well.

Thus we see that chemistry is creating an entirely new era for the farmer, to which he is going to be required to adjust himself. Already the introduction of new and improved machinery has made a mechanical engineer of him. Now he must become a chemist as well. With the introduction of powered farm implements the farmer has gradually found himself in the position of a manufacturer. He was forced to adopt production methods to hold his place in the race. Now he finds himself going through much the same stage that the manufacturer found himself in a quarter of a century ago. He finds that he has been throwing valuable products out the back door. In the field of manufacture more than

one millionaire has been made by the discovery of a way to utilize an apparently useless, or perhaps even decidedly undesirable, by-product. The same may be true in farming in the next decade.

During this period of adjustment to new conditions, the farmer as we know him, may completely disappear. The utilization of the by-products of industry has had much to do with the disappearance of the small manufacturer. With the small amount of by-product material which he possessed, it was not economical to utilize it. The large manufacturer, besides other economies, had this additional source of profit.

At the same time the farmer may be greatly benefited by this new industry, whose factories will need his labor. Dependent as it will be upon plant crops, it may be expected that initially, at least, the work will be somewhat seasonal, the season following naturally the time of harvesting the crops. Thus the farmer may find a ready market for his time in off-periods. The factories must of necessity be in the midst of a farm section, so that it will not be necessary for the farmer to migrate to a city to get work in them; a procedure which would in general be quite impossible for him, since there are always farm animals which require some care.

Recently the profitable occupation of such off-season time has entered more and more into the

farm problem. Not many years ago the farmer's slack period could be used for bringing in the winter's supply of fuel from his woodlands. He is finding it necessary now to buy his fuel. Thus he no longer finds this or similar employment on his own land to pay him during the winter months. At the same time purchasing such materials demands that amount of additional income, which he does not find coming in. Any project, then, which offers employment for this unused time will be of great benefit to the farmer. The manufacture of products, for which he himself supplies the raw material, seems to offer an ideal solution to the problem.

Chemistry and Cotton

There is no more interesting story of the conquests of chemistry in the field of agriculture than that which has so often been told recently concerning chemistry and the cotton industry. While this story has been often repeated, it is nevertheless always new. It is gaining in length each time it is repeated, and not, as in the case of gossip, because each teller draws a bit upon his imagination, but because each time there are new facts to tell. The story, of recent years, has grown like a snowball. It is difficult, now, to imagine that it had such a small beginning. It seems that it must always have been at least of moderate size.

If we go back to early history we find that people were using cotton for the making of clothing. The records are found among various races. But, until recently, no one began to roll the snowball. No one introduced the magic forces of chemistry into this industry. To the Chinese must go the credit for first using any part of the cotton other than that useful in making cloth. Early in the seventh century it appears that they were using the oil of the cotton seed for purposes of illumination and were feeding the remainder of the seed to the cattle. It was fully a century later that this part of the plant gained any commercial significance outside of China. Well into the first quarter of the nineteenth century the cotton seeds were regarded, in America, as a nuisance. They were left outside the cotton mills to rot or were dumped into neighboring streams. This practise was so prevalent that it became a sanitary nuisance, and it was necessary in many places to pass laws regarding the disposal of these seeds. It was unlawful to retain any seeds that were not being kept for planting. Those not so needed were burned by the hundreds of tons.

In the meantime the people were not unmindful of the possible value of the oil in these seeds, and societies for the purpose of encouraging agriculture or invention offered prizes for methods of extracting the oil. In spite of this

encouragement the oil was not extracted and the prizes were unclaimed.

Eventually, however, a small amount of oil was pressed out by rather crude methods and used for illumination. Someone discovered that this oil was edible, and then trouble began. Unscrupulous dealers began to use it as an adulterant for olive oil. Others put some of it in lard that was intended for use in the colder climates. On the whole the oil was not a desirable newcomer; neither did it produce for the cotton growers any increase in income that was at all noticeable.

It remained for the chemist to enter this field before any real headway was made. The first of these chemists was John Mercer. His name is well remembered because it is still associated with his invention, a method of making mercerized cotton. While it did not offer any new uses for cotton, it did make the material more attractive to the eye and perhaps increased its sales somewhat. The chief contribution in so far as the industry was concerned, was perhaps to turn the attention of chemists to this new field. Since that time the development has gone forward with an ever-increasing speed.

The first contribution to the art of separating the oil from the seed was the invention of a machine which separated the meat from the hull. This resulted in a great increase in the oil ob-

tained, for that which was previously forced into and absorbed by the hull, was now saved. The resulting seed-cake, made by compressing the seeds from which the oil and hulls had been removed, was likewise more valuable than before; it was relieved from the extra bulk of the hulls. Because of the high nitrogen content, these cakes began to find a use as fertilizer, and because they were now freed from the shreds of the hull and possessed a high protein content, they also became popular as a concentrated cattle-food.

But the process of separation of seed from hull carried large quantities of seed along with the hulls. The fragments of seed became entangled with the remaining cotton shreds which were not removed in the initial ginning process. It became, therefore, economical to remove these by what might be referred to as a second ginning process in what was called a linters machine, these residual short shreds being called "linters." This produced a new product which, while not greatly sought by the open market, nevertheless found a place in the making of battings, mattress fillers, and so on.

Cotton Billiard Balls

It was these four natural products, oil, meats, linters, and hulls, with which the chemist began to work. The cottonseed meal still finds its main

use as fertilizer or as animal food, altho it has been found that it can be made sufficiently attractive for human consumption. The oil, however, has had wonders performed on it. Through the use of nickel, to promote the action, it can be treated with hydrogen in such a way as to produce a solid material resembling lard, which has now become so widely used as almost to result in the displacement of lard in modern cooking. Many of our salad and cooking oils come also from this source.

The chemistry of linters is also the chemistry of cellulose, which has already been discussed. Here the changes have been even more magical than in the case of the oil. Some of the products of linters, as given by Mr. C. S. Meloy, of the United States Department of Agriculture, are high explosives, surgical dressings, new skin, artificial leather, sausage casings, roofings and floor coverings, wearing apparel, lacquers, varnishes, photographic films, toilet articles, and billiard balls. Our ancestors would have been astonished at the thought of making billiard balls from cotton.

Now the chemist is attacking the hulls. As yet his answer as to what to do with these is not complete, but he has already made many suggestions. The hulls contain such materials as furfural, acetic acid, alcohol, tar, and other hydro-carbons, as well as potassium and com-

pounds of carbon and sodium. These can now all be obtained from the hulls, but the methods of recovery are not yet economical. This improvement in methods we can be reasonably sure the chemist will make eventually.

To what extent does this help the cotton-grower? Mr. Meloy answers: "The increased use of cotton goods, resulting from enhanced attractiveness and durability due to mercerization, is problematical, but the diverting of 6,305,775 tons of cottonseed in 1927 from the refuse pile into channels of consumption produced approximately $250,000,000 of value that would never have existed but for the intercession of chemical research. It is estimated that possibly two-thirds of this created value reverts to the cotton-grower and thus becomes an offset to the increased cost of production that has occurred during the period in which cottonseed became valuable."

V

OUR MECHANICAL WONDERLAND

Light Waves—the Foundation of Modern Industry

In discussing mechanical accomplishments of man the first thing which naturally comes to one's mind is the remarkable developments which have come through our modern methods of quantity production. One thinks of the Ford car and the dollar watch as the outstanding examples of what can be done by these methods. Few persons have any real idea of what it is that has made these things possible. The answer is, increased accuracy of measurement. Without this our present manufacturing methods would be impossible.

Our first measuring instruments were simple wooden scales. These were eventually replaced by steel scales, which were considered a great advance. Later came the so-called vernier and micrometer measuring devices. These were capable of measurements to a thousandth of an inch, and a good guess could be made to a ten-thousandth. Such refined measurements were considered as unnecessary except for very special jobs, and had anyone suggested their use to speed up production he would have been con-

sidered crazy. To measure to such accuracy would have been expected to slow up production. Yet this is not the case.

Production in quantity requires that all similar parts of like machines should be interchangeable. A number of similar cars can be completely dissembled, their parts mixed up, and an equal number of similar cars reassembled from the pile. In the same way if a part of my typewriter breaks it is possible to obtain a new part and know that it will fit. I do not have to take the machine to the manufacturer and have him make a part specially to fit this particular machine. In the old days every machine was a different unit. No parts of two machines were interchangeable.

Now, in order that certain parts of two cars may be completely interchangeable it is often necessary that they be exactly of the same size to a ten-thousandth of an inch. It is obvious, then, that the machines which made these parts must be exact to an even closer limit. These machines must likewise be made by other machines, and so on. We are therefore driven back to the point where the micrometer devices, already referred to, are not good enough. In the end we are driven to making our measurements in terms of light waves. These enable us to measure to as small a unit as a five-millionth of an inch.

Light-wave measurements can be made with an instrument known as an interferometer, which functions through its ability to bring together two rays of light in such a manner as to produce darkness. Through the use of this instrument hardened steel gage blocks are polished off to a similar degree of accuracy. These come in sets, the largest being made up of eighty blocks of different sizes. Such a set will enable one to make 300,000 separate measurements. These blocks are as carefully guarded as jewels. If one should happen to fall even a few inches, it could no longer be relied upon until it had been checked against some of its fellows. So carefully are they kept that the average machinist would not see one of them in a lifetime; he would be provided with substandards made from the originals. It is upon such gages and such accuracy that our modern production methods depend.

Suppose that we are to make a particular part for a machine two inches long, and that the tolerance is a ten-thousandth of an inch. No part could be produced, regularly, exactly two inches in length. If it could, that would mean that it was correct to a millionth or a billionth of an inch, or as high as you wish to mention. It would be perfect. This we cannot do in practise. Some allowable limit must be set. If this is a ten-thousandth, then the part must be between

2.0001 inches and 1.9999 inches in length. We would set our machine to manufacture within these limits, and we would check the product with what might be called a "go—no go" gage. One part of it would have an opening 2.0001 inches in length. If the part fitted into this it would be short enough. Another opening would be 1.9999 inches in length. If it fitted into this it would be too short. Thus it must enter the long opening but not the short in order to pass inspection. A great variety of gages, usually made especially for each job, serve to control the product.

Another great factor in production manufacture is the use of so-called jigs. Suppose three holes are to be bored in a piece of metal in a certain geometrical relation to each other. No two men will bore these in exactly the same positions. Even an individual will not be able to space these off twice in exactly the same way. But suppose he is given a piece of metal which he can clamp to the piece he intends to bore, and which has holes in it spaced as he wants to bore them. Then it is impossible for him to use his drill in any but the right place. He, or anyone else, will make parts which are interchangeable. In the same way if a single machine is supplied him with three drills held rigidly at the proper distances, and all made to work at once, he is again prevented from boring in any but the

correct way. Such gang drills frequently have large numbers of individual drills and will bore a large plate at one time. Large stamping machines are also used to stamp out parts, all of which are alike within close and predetermined limits.

Such, then, is the basis of our modern manufacture. It is a matter almost entirely of our ability to make accurate measurements. Without this ability our modern civilization would be quite different from what it now is. There would be no traffic problem, for example; few of us could afford automobiles. A Ford would cost more than a Rolls-Royce now does.

The Steel Chef's Job

We have already discussed the numerous things that the chemist can do with steel to make it harder and more brittle, or to make it tougher and more ductile, or to give it any one of a number of properties or combinations of properties. But when the chemist has finished his job and has turned over an ingot of iron to us there is still a great deal to do to it before it is ready for use. It must be rolled out, drawn out, or in some manner shaped for the particular job for which it was intended. This mechanical process is just as important as the chemical one, for the ultimate strength is greatly influenced by it.

Perhaps in the manufacture of structural steel no greater care is taken anywhere than in the manufacture of steel cables for suspension bridges. In one large mill no less than four per cent. of the employees are highly paid specialists who do nothing but test the material. In such a plant the original steel ingots are made up of high-grade scrap-iron mixed with pig-iron. The iron is carefully selected to avoid possible contamination with other metals, then is melted in forty-ton lots and poured out to form thirty ingots. As these ingots are later needed they are heated up over a period of ten hours. They could be heated much more quickly, but this process affects the ultimate strength of the cable which is to be made. The time has been carefully determined from long experience. When hot, the ingots are rolled out into strips four inches square. Fourteen per cent. of the top and two per cent. of the bottom end are cut off and scrapped, as being of inferior material. The remaining portions are then rolled out into bars two inches square, and the outside layer of these is cut off to get down to better metal. The bars are then stored until needed, those from each ingot being segregated. The steel from a single ingot is marked and kept track of through the whole process, so that in the event that any part of it shows inferiority, all the parts made from

the ingot can at once be found and examined or scrapped.

In the next process these bars are again slowly heated and rolled out into rods. These are tested for size and strength. A long heat treatment follows, after which the material goes through a bath of fine carbonaceous matter and from there directly into a lead bath. Pickling in a bath of fine hydrochloric acid follows this and quickly shows up any surface defects which would otherwise go undetected. The bars are then rinsed to remove most of the acid and run through limewater to neutralize what may remain. A long heating process removes any hydrogen which may have gotten into the metal through the pickling process. At this stage the rods are cold-drawn into wires, which are then galvanized to prevent rust.

This ends the process except for testing. The wire is tested for strength, elasticity, elastic limit, bending, thickness of galvanized coating, and a dozen other things. They are made up into cables and these are again tested. One large tensile-strength machine in the United States will exert pulls of a million and a half pounds. Both ends of every coil of wire that goes into such cables are tested separately for a great many properties.

When the cables are shown to meet specifications in every way they are ready to go into the

structure of a suspension bridge, which, after all, is nothing but a roadway hung upon wires. Even then, in spite of all the tests, we cannot be sure that all will be well. If the entire process has not been carried out with the greatest care the wires may change their structure and weaken after being put into place, and no longer be capable of sustaining the loads at which they were tested before being used. Only recently it was found necessary to stop work on a 1200-foot span because it was found that in a half-strand of cable 130 out of the 180 wires were broken. This occurred before the roadway was entirely in place. The wires had been made by a process other than the one just described. To rectify the defect in that cable will, of course, involve an enormous expense, now that the cables have all been spun and placed. The job of the bridge-chef in the steel kitchen is an important one, even tho the chemist may have provided him with the raw material.

Flowing Metals Together

Our first construction material was wood, and methods of handling wood have been handed along with those of other materials as they came into use. This has been the case with metals. Wooden beams had to be bolted together; you cannot melt wood and make it flow. Thus, when we began to use metal we bolted it too, altho

it can be melted and made to flow together into a single strong piece of metal. The result has been that only recently has suitable welding apparatus been devised to allow us to use metals as metals and not as wood. Now welding appears to be coming into its own.

Welding has many obvious advantages. It forms a more rigid whole than is usually obtained by bolting, as the structure is a unit and not a number of pieces held together by angle-irons at the joints. The material is not weakened by bolt-holes, nor is careful alinement of parts, to bring bolt-holes together, necessary. Welding also has the advantage of quietness. The noisy riveting hammer has no place in welding. Also—and this is of great importance—in welded buildings and bridges it has been found that a saving of about forty per cent. in material can be effected. The saving is due partly to the increased strength—as the result of elimination of rivet-holes—and partly to the elimination of gusset-plates.

Welding has gained a far greater headway in manufacture than in building construction. Not more than one per cent. of dynamo and motor cases are cast now, whereas a few years ago they were all cast. They are now fabricated from standard steel parts. The same is becoming true in motor-car manufacture. In one low-priced car

tearing down our buildings almost before they are completed. It is a surprize to a visitor in America to see perfectly good buildings, capable of years of service, being dismantled. He is likewise surprized at times to see some of our automobiles that are being sent to the junk-heap. This appears to be a form of American extravagance. As a matter of fact, it is probably one of the greatest, if not the greatest, factor in our prosperity. Suppose we were to find in a storehouse a car which cost two-thousand dollars ten years ago. Suppose that every part of it was as good as when it was placed there, and that it had never been used. How much would you give for it? Certainly not much. By improved methods of manufacture a thousand-dollar car to-day is as good as that old one in so far as the workmanship is concerned. But your car to-day will be lacquered and not painted. The finish will be much more enduring. It will have chromium plating instead of nickel. It will have four-wheel brakes, the engine will be more powerful, it will be built of better steel, the tires will last three times as long, and so on. You could not give the old car away. Our idea of what a car should look like also has changed. The old car would be uneconomical to run.

In the meantime the factory equipment, too, has changed. A manufacturer who tried to make the modern car with the old equipment would

find himself paying more to make the car than he could sell it for.

Let us consider another type of obsolescence. Let us assume that a machine has been designed to turn out a particular product and that the machine is perfect. Now let us increase our production until we have two, ten, and eventually twenty, of these machines at work. While each machine is perfect in itself, it has become, nevertheless, obsolete for our purpose. Why? In the first place we are using up too much floor space. Floor space varies as the square of the dimension, while volume varies as the cube. Using larger machines would give the same capacity with a reduction in floor space used. With floor space goes cost of heat, light, ventilation, and so on. In addition a few large machines will mean fewer attendants. Thus wages and floor space are saved. It has been estimated in one case that the replacement of twenty small units by four large ones resulted in a saving of four-fifths of the floor space. There is also a saving in cost of inspection, lubrication, adjustment, cleaning, and in power, through the use of fewer but larger motors.

In special cases, where the process requires heat, there is also a saving here. The surface from which heat can be radiated goes up with the square of the dimension, while the volume goes up as the cube. Where dust or fumes must

be removed there is a saving in the number of flues which must be installed.

But the big machine may not be the same as the small one. We may be able to use motor instead of man power. We may be able to install automatic control. We may be able to substitute a continuous process for a batch process, and so on. All these make for great savings and more uniform product. Thus a perfect machine may become obsolete because it is too small for the output. Too many units are required.

Again obsolescence may be brought about overnight by a new invention, or by a change in style. Obsolescence is something which cannot be written off at so much per year as in the case of the ordinary depreciation. It comes upon us more like a fire in most cases. But in the end it is the recognition of the existence of obsolescence which goes to make a great manufacturing nation.

Mechanical Donkeys for Logging

Logging, like almost every other industry, has adopted the methods of large-scale operation. One normally thinks of a logging camp as being mainly a winter affair dependent upon the snow for making the hauling of logs easier. As a matter of fact, logging is now an all-year occupation, and the winter, because of its snow, is the least favorable season. All logging is now done

by power machinery. In a strictly modern camp one will not see a single horse or mule. It is because of this change that the snow now offers an obstruction rather than an advantage.

In modern logging the first necessity is to construct a railroad right to the point where the logs are to be harvested. This is often a difficult and expensive thing to do, for the country is almost always rough and rocky. It is usually necessary to span a few gullies with trestle-work. All this takes time and a great deal of capital.

In harvesting a particular region a particularly tall straight tree is first chosen, which becomes known as the spar-tree. It will be the central point of all operations in that region, and the railroad will be built up to where it stands. This tree is stripped of its branches and the whip-like top is blown off with dynamite. It is then carefully guyed by steel cables stretching in all directions to other trees or stumps. In the logging districts on the west coast such a tree may be frequently as much as ten feet in diameter. When thoroughly guyed it has the appearance of the framework of a great circus tent.

From this tree cables will be run out to a second tree, called a tail-tree. This, depending upon the contour of the land, may be 1000 to 5000 feet from the spar-tree. An overhead cable carrying what is known as a bicycle—a pair of

wheels which run along it—is an important connection between these two trees. This cable is used to draw in the immense logs. A large pair of tongs grapple the log, which is raised into the air and carried overhead to the spar-tree. As such logs gain speed, and go sailing through the air, they frequently strike trees as much as a foot or more in diameter and knock them down by sheer momentum. If the contour of the land does not permit the use of a wholly overhead system, one end of the log will be raised and the other allowed to drag. The deep gullies that are cut into the ground by the tree-ends are astonishing.

When the logs are collected at the spar-tree they are loaded upon railroad trucks, which are held together by the logs themselves. The ends of the logs rest upon a row of spikes which top the truck. This avoids the necessity of bringing sawing equipment into the woods to saw them all into equal car-lengths.

When the logs are taken to the nearest waterway they are made up into great rafts held together by a crib. Such rafts are often as much as a thousand feet long and may extend to as much as thirty feet below the surface of the water. Often they are towed to a destination a thousand miles or more from where the trees grew.

Thus we see that the donkey driver, with his long snake whip, has disappeared from the

woods. In his place we have now a skilled engineer. The blacksmith's cabin has been replaced by the machine shop. These shops are often so complete that they do all their own foundry work. They cast their own brake-shoes for the trains; their lathes can turn down a locomotive wheel. Thus has logging, like everything else, given way to large-scale operation by power machinery. You are as likely to see a horse-drawn vehicle in a logging camp as to see one used in an automobile factory to transport parts from one department to another. The mechanical engineer has invaded the woods.

Have We Become Tunnel-Minded?

In spite of the fact that the world has become air-minded of late, there are apparently a number of individuals who have become quite the reverse, tunnel-minded. They are digging deeper and deeper into the earth and building longer and longer tunnels. One of the most interesting of these is the Holland Tunnel, which connects New York and New Jersey. This is of particular interest because it is the first great vehicular tunnel. The entire problem was greatly complicated by the necessity of providing certain protection against poisonous exhaust gases from the motors of the cars passing through. The principal contribution to tunnel-building which has been made by the Holland Tunnel was the

solution of this problem. It has been so well solved that it can be said that the air in this tunnel is purer than that found in our city streets where similar traffic conditions exist. This is all taken care of automatically in such a way as to be almost certain of no possible failure, yet additional safeguards are set up in automatic signals which will give ample warning should there be any approach toward danger. The air is constantly analyzed.

The building of this tunnel has stimulated the building of similar tunnels elsewhere. A tunnel is being built under the river at Detroit to connect with Canada. A tunnel is being built connecting Oakland, California, with Alameda. This latter is of interest mainly because it is not a true tunnel at all, but a series of segments, from two hundred to three hundred feet long, each precast in steel and cement, sunk in place and joined end to end.

The Moffat Tunnel through the Rockies, which was recently built, held the title of America's longest for only a few months. It was superseded early in 1929 by the tunnel through the Cascades, about 100 miles east of Seattle. This tunnel is exceeded in length by but four others—the Simplon, St. Gothard, Loetschberg, and Mont Cenis tunnels in the Alps. It is about eight miles in length.

This tunnel is of interest because of the

method of construction. In order to build it in the record time of three years it was necessary to have as many working surfaces as possible. To accomplish this a pioneer tunnel, a bit to one side of the main tunnel, was constructed and kept ahead of the main tunnel. The pioneer bore was eight feet by nine in cross-section. It tapped into the main tunnel at about every fifteen hundred feet. Through this the supply trains brought in the supplies, and through it the rock was removed. It also contained all the cables which were necessary for the work. In this way the main tunnel was cleared of all obstruction and additional working faces were made available. As soon as a section was built, the cement lining could immediately be put in place, the workers being absolutely unhampered by what was going on further in the tunnel. This method of construction was found to be entirely successful and will doubtless be repeated in future borings.

At the present time the impetus which has recently been given to tunnel building has resulted in a reconsideration of such long-talked-of projects as the Dover-Calais Tunnel. Active steps are being taken to bring this into being. The building of a tunnel from Gibraltar to Africa seems also a not-too-impossible thought to entertain. It is estimated that such a tunnel would cost $1,930,000,000. While this seems a

large sum, when one considers the effect it would doubtless have upon northern Africa it would appear that the benefits it would be likely to confer would wholly justify the enormous expense.

VI

MAN DEFIES THE ELEMENTS

Push-Button Weather

PRIMITIVE man was wholly at the mercy of the elements. Not until he built his first shelter did he attempt in any way to shield himself from the weather. And it was long after this that he built his first meager fire to protect him from the winter's cold. At this stage matters stood almost to the present time. While great discoveries in science were made, while astronomy, and chemistry, and mathematics flourished, very little was done for human comfort. Man advanced little from the primitive type of open fire, except merely that he learned to avoid some of its smokiness. It was Benjamin Franklin who invented the first stove—the first advance in centuries. With the invention of the stove came house-heating for the first time. Yet those who have lived in a stove-heated house know that it was the modern furnace which really gave us warmth in winter.

Now we are ready to do something about the summer's heat. At present our homes are at best equipped with but a few electric fans, which produce not more than a ripple. They are about

as effective against the summer heat as was our ancestors' open fire against the cold. They are only a beginning in the direction of all-year comfort.

The theaters have been leaders in this direction. When one steps into a modern theater on a hot summer's night he now expects to find ideal weather inside. Many patrons admit attending the summer theater for just this reason. Some of our large department stores are following this lead, and shoppers are showing their approval. Ideal weather can now be manufactured at will. It is common in our large public gathering places; it will soon be common in our homes.

How is ideal weather made? In the theaters in New York the patrons must be furnished with thirty cubic feet of air per minute, of which twenty-five per cent. must be brought in from outside. The air which is brought in is first cleaned of all dust and smoke by washing it out with a water spray. The air is then passed through a chamber which is maintained, by artificial refrigeration, at a temperature of about 42 degrees Fahrenheit. If the air is colder than that as it comes from outside, this process will add moisture, for the amount of moisture air can hold depends upon the temperature. If the air is hotter, it will, in general, lose moisture, unless the humidity at the higher temperature

happens to be low already for other reasons. Thus, as the air passes from this chamber, it will in the end always have the same amount of moisture; that amount which the air at 42 degrees can hold at saturation. The next process consists in merely heating the air up to 70 degrees Fahrenheit, after which it is passed out into the theater. At this point the humidity will be about sixty per cent. Part of this air is later drawn out and recirculated with the air coming in from outside. The temperature and humidity just named are considered ideal for humans.

Manufactured weather is now figuring largely in our research. As a result laboratories with push-button weather are becoming common. At Johns Hopkins University zero weather and fogs can be produced at will for the purpose of studying common colds. The Bureau of Mines is studying the behavior of airplanes in manufactured weather. As airplanes must go from hot to cold altitudes and from high to low pressures in a very short time, these studies are valuable. Here the airplane can be kept stationary in all kinds of complicated tests, and the weather can be varied in a manner which would only rarely happen in practise, and which might cost many lives if it did. All kinds of extremes can be tried out at leisure.

Manufacturers of cameras also maintain extensive research laboratories for the study of

weather effects on their products. Both the cameras and films, as well as developers and other chemical products, are taken to all parts of the world. Their cameras may find use in the arctic snows or in the tropical jungles. At the throw of a switch the weather conditions of these places may be produced in the factories.

Museums and libraries are rapidly installing artificial weather. The effect of dryness on book-bindings is all too well known. Also the effect on the paper is great. With proper conditions of humidity and the constant circulation of fresh warm air through the stacks, the books almost never disintegrate. Fresh air for books seems almost as important as fresh air for humans. In museums the paintings are greatly damaged by the abrasive action of dust. The removal of dust also saves a great deal of labor in cleaning—cleaning which is frequently damaging to the article cleaned. The addition of water to the air also prevents rare old pieces from falling apart. It keeps them in a fresh state.

There can, of course, be no question but that ideal weather is a health factor. It has been found to have an effect upon blood pressure, respiration, pulse rate, and body temperature. All these directly affect the health. Wherever humans are required to work in polluted atmospheres, provision is now being made to supply plenty of fresh air. A few years ago there was

not an adequately ventilated chemical laboratory in the country. The new ones are all providing for artificial weather.

At present our air-conditioning systems are efficient in the case of large buildings requiring large amounts of air. For our homes they are not yet built in a manner which makes them feasible to operate. This, however, we may confidently expect will soon be accomplished, and we may look forward to seeing our residences supplied a few years hence with air that will be the same all the year round. We shall have completely conquered the weather.

Air Sewage

Much of the necessity of air-conditioning has been brought upon us by the cloud of smoke which is poured out into the atmosphere by the numerous heating plants of the city. We are beginning to learn something of the necessity of purifying our air, just as we have learned the necessity of purifying our water supply. If the water comes to us polluted, we must purify it ourselves before use. The same thing applies to the sewage of the air, which is now being discharged, in most cities, almost without hindrance.

Most cities have some law which prohibits dense black smoke. This takes care of only part of the discharge, however; and while the densest smoke does the most damage in smudging build-

ings, draperies, etc., there are other unseen components of smoke which are fully as undesirable. About ten per cent. of the weight of the coal comes out of the stack, and of this about two-tenths is unconsumed carbon. It is desirable to save this, as it is the part of the coal which produces the heat; and, in the case of large installations, an attempt is made to save as much of it as possible. It is not economical to save it all, however. The remaining eight-tenths of that which comes out of the stack is mainly ash, which, apart from the dust which it creates on the street and in our homes, is more or less harmless.

Along with these solid products come gases; for example, carbon monoxid, a poisonous gas which, however, is soon converted to carbon dioxid and so gives no trouble; or sulfur dioxid, a really harmful gas. This latter combines with water vapor to form sulfuric acid. This is very active, and in some parts of New York is so plentiful in the air that it has eaten away metal cornices of buildings and has made it necessary to close up metal ventilating systems because of holes eaten in the metal. It is destructive to everything it touches. Its action on fine draperies and other delicate materials is all too evident. The damage this acid may be expected to do in a museum of art needs no comment.

In addition to the damage which is done di-

rectly by smoke pollution there is another vital factor. The smoke screen cuts off the ultra-violet radiation from the sun during the greater part of the year. That this is a vital factor of health, and particularly in the bone-growth of children, there is no longer any doubt. It has been proved over and over again. This factor can be replaced to some extent by treatment with vitamin-bearing foods and by irradiation with artificial sunlight. Too often, however, this is not done. It requires, at times, much effort on the part of the individual, and often the expense of such treatment is beyond the reach of those who need it most. Here is something given to us by nature, of which we have been robbed.

But how to get rid of the smoke screen, that is the question. At the present time there are many types of smoke collectors intended for the stacks of large power installations. The smoke is caught by these in various ways. In the simplest type, the smoke is merely trapped by filtering it through some material such as metal wool. It may be caught by passing it through baffles or through zones of still air.

The more elaborate smoke collectors precipitate the solid matter by fortuitous air currents. One of these, by a rotary device, throws the smoke and dust to the outside of the machine where it is collected in much the same way that milk and cream are separated. Another employs

the principle of the whirlwind. When the air is set into rotation, solid particles tend to settle in the center of the vortex as leaves collect in the center of a small whirlwind on a gusty day in autumn. Still another smoke collector operates electrically. The smoke circulates between large plates which are electrically charged to a high potential. The smoke particles, becoming charged by induction, are pulled over and precipitated on the plates, from which they later fall.

By such devices large quantities of smoke are collected. One single power plant collects over a hundred tons of smoke a day. But there is little incentive to do this. The smoke is no use after it is collected. It will not pack solid, so it cannot be used to fill in waste land. It will blow off open trucks, and so can only be transported with difficulty. It cannot be dumped into a stream, as it will not settle to the bottom. It pollutes the water. Thus there is no likelihood that anyone will go to the trouble and expense of collecting such material unless forced by public opinion. This, however, is being aroused. Unfortunately, no collecting device exists which can be used on small installations. Perhaps one will be devised when the public is sufficiently interested. In the meantime we can look for a major improvement only in the use of better coal and in improved firing methods. This is a problem for

engineers and scientists. Perhaps it will mean that eventually our heat and power will come into the cities through outside electric and gas plants.

Permanent Peace with the Mississippi

Against no force of nature is man more helpless than against the flood, once it is upon him. The water rises, relentlessly, inch by inch, until it becomes a great torrent carrying everything before it. The story has been so often repeated that it is a familiar one to all. We have heard of it recently in the Mississippi Valley. We have heard of it in Vermont.

But in the case of the Mississippi, at least, we are preparing to end these disasters. An appropriation of $325,000,000 has been made to provide engineering works for the permanent protection of 20,000,000 acres of the world's most fertile land. When this work is ended it will form an enduring monument to our generation. Long after the Woolworth Tower has been pulled down to make room for other structures, and perhaps even forgotten, the Mississippi will be flowing quietly between the levees which we are now providing. Perhaps long after the last vehicle has passed over the Brooklyn Bridge these engineering works will be performing their duty. We shall have permanent peace with the Mississippi.

Too long have we been trying to grab more and more land from this river. True enough, we can confine the river to a narrow bed, if we make the levees high enough; but there is a limit beyond which this can go neither safely nor economically. We can, however, use the reclaimed land part of the time. To do this the present plans call for confinement of the river, under normal conditions, to a comparatively narrow bed, and a secondary line of levees is to be built which will take care of the river temporarily in flood times. Engineers are building what are called fuse-plug sections. These are three feet lower than the regular levee, and over them the water will flow when floods begin to menace. They are provided wherever drainage facilities will permit their use. One, forty miles in length, will be provided just below Arkansas.

Another protection device is the so-called spillway. This is a construction of masonry sills which can be operated mechanically to lower the water level when it reaches dangerous heights. The sills can be opened almost instantly. Such spillways are to be provided for the protection of New Orleans.

The basin of the Mississippi has now been thoroughly studied, and in many places it has been found necessary to relocate the levees. This has often resulted in the necessity of cutting

across old homesteads. But such is the march of progress and the cost of safety.

The levee forms, for the most part, the only kind of flood protection whose cost is consistent with the value of the land reclaimed. Levees vary somewhat in size and shape, depending on the nature of the soil. For loam, which predominates, they are built with a slant of about one foot in three and a half on the river side and about one foot in six and a half on the land side. The crown is about ten feet across. On the river side the levee is protected by a mat of willow reeds woven into galvanized steel cable. The reeds are spread out on the water and sunk by piling stones upon them. More recently a concrete mat has been devised. This consists of concrete slabs held together with steel cable.

When the work is complete it will constitute the greatest achievement in flood protection that the world has ever known, and there will be no question about its safety. Wherever experts have differed as to the best method to be used at any point, the safe procedure has in every case been followed. Thus does man control the natural forces which threaten him.

Men Killed by Milk Explosions

While it may not always be the unexpected which happens, as has so often been said, nevertheless the unexpected frequently does happen

in a way which is very mystifying. If we were to warn workmen of the presence of glycerol nitrate, cellulose nitrate, or of trinitrotoluene, every one would keep at a respectful distance. The very names of these seem to frighten him. But if we were to post up a sign saying "Danger, Flour!" or if we were to warn of the danger of cork, milk, chocolate, or a dozen other materials, we should be laughed at by most men. Have they not used these materials all their lives? They have never seen a milk bottle explode nor a cork suddenly fly to pieces.

It is this attitude which makes it so difficult to guard against explosions of these substances, explosions which take a tremendous toll of life and property every year. How do such explosions come about?

Explosions may be placed in two classes, physical and chemical. A physical explosion is represented in the blowing out of an automobile tire. The wall fails to hold against the physical pressure inside, and a sudden release of the pressure, an explosion, takes place. A boiler explosion due to excess steam pressure is also of this type. A chemical explosion is one in which a chemical action suddenly produces large quantities of gas which build up a high pressure at a very rapid rate. This leads to a physical explosion.

Now any material which will burn, will in

general, produce gas. The rapidity with which the gas is produced depends upon the rate of combustion. If a cork is in a solid piece, as we are accustomed to see it, the combustion can take place but slowly, as the flames must burn their way into the interior of the mass. But suppose we grind the cork to a very fine powder and shake it up in a box filled with air and then set a flame to it. It will explode! Every individual dust particle is surrounded by air containing the necessary oxygen for combustion. Every particle can burn at once. The result is that gas is formed at a very rapid rate, and if the dust is in an enclosed space, the escape of gas must take place with the attendant destruction of the container.

Almost every industry is subject to the dust hazard. Of a number of cases reported, one was due to pyroxylin lacquer dust, resulting from the spraying of automobile bodies; eleven were sulfur dust; four, hard rubber dust; sixteen, starch; nine, sugar; twenty-seven, wood dust; six, cork; two, aluminum; six, fertilizers; three, spice; two, pitch dust; one, rosin; two, powdered milk; two, chocolate and cocoa; two, celluloid; and three, cotton dust. This gives some idea of the diversity of materials subject to this hazard. There is almost no dust which will not burn.

Most of these explosions were caused by hard material getting into the grinders and producing

sparks. Next came friction between belts and pulleys, as a cause of the explosions. This produces static electricity, which may produce a spark. Open flames and broken lamp bulbs were also among the causes of these explosions. In one case the spark was due to a broken elevator chain. In another it was caused by sliding boxes along the floor.

Such explosions, difficult to ward against, must be considered a major danger wherever dust exists. And they are usually severe. Dr. David J. Price, of the United States Bureau of Chemistry and Soils, writes:

> The Bureau has obtained records of more than 300 of these explosions. In seventy-eight dust explosions 498 persons were killed and in 106 explosions 878 were injured. In 144 cases the property loss amounted to $39,706,108, an average of nearly $246,590 for each explosion. The economic importance of this problem can be more readily appreciated when it is realized that at least 28,000 industrial plants, employing over 1,324,000 persons and manufacturing products of an annual value in excess of $10,000,000,000, are subject to the hazard of dust explosions.

Battling with Icebergs

With the increased necessity for year-round shipping, with the increased number of water-power electric-generating stations, as well as other year-round activities on main waterways,

has come into being a new kind of engineer, the ice engineer. It is his business to break up ice jams which may occur and, in so far as possible, prevent their recurrence. Anyone with a small amount of engineering education will realize the difficulties of such a job. The first part of it, prevention, is not so difficult. An understanding of the flow of water and of the theory of ice formation is frequently all that is necessary to enable the engineer to formulate methods of preventing an ice jam. Once the ice jam is formed the matter becomes decidedly more difficult. Treatment of such a condition usually requires heroic measures. This is because an ice jam usually involves thousands of tons of ice, and because the amount of heat required to melt ice is enormous. To melt ice requires eighty per cent. as much heat as is required to raise the temperature of the resulting water from freezing to boiling temperature. To melt ice is, therefore, clearly not to be thought of. The first recourse, usually taken by the inexperienced, is to blast out the ice with dynamite. This is, in general, out of the question. We all know the great effort required to blast a cut through a mass of rock in railroad or highway construction. It is a process requiring weeks for even a small cut. An ice jam requires immediate relief to avoid possible floods. In addition the ice, being more elastic than the rock, is less easily shattered.

The most successful work that has been done in clearing ice blocks has been accomplished through the use of thermite. The use of thermite is like pouring white-hot steel into a crack in the ice. The molten metal is produced by the action of aluminum and iron oxids. This has a variety of effects. In the first place, the high temperature causes great expansion in the neighborhood of the crack into which it is poured. The unequal expansion at this and other points results in cracking, for the same reason that a cheap glass will crack if hot water is poured on it at one spot. In addition to this effect the disintegration of the water into its components, hydrogen and oxygen, produces an explosive mixture of great violence. It is not thought, however, that this is of great importance, altho it all helps. One of the foremost ice engineers, Dr. Howard T. Barnes of McGill University, Montreal, is of the opinion that the effect is principally due to the transmission of heat rays through the ice. These are finally absorbed along seams and various points of inhomogeneity. Such rays, he thinks, may travel in the ice for some time and set up strains, due to expansion, which are not at once evident. A charge of thermite, when set off, has little immediate effect. It is usually many hours later that the ice begins to crack up. In this way large icebergs have been destroyed, and it is contemplated that further

improvements on the method will make it possible to destroy all icebergs which threaten to drift into the ship lanes. The possibilities of this fascinating field of engineering are just beginning to be realized.

Fires that Start Themselves

One of the problems with which man must constantly struggle is that of fire prevention and control. There are few causes of fire which we cannot directly eliminate. And yet we go on having fires, costly in life and in property, daily. It is estimated that among farmers, where the availability of fire-fighting equipment is not great, one-sixth of the net profits of the farmer are wiped out each year by fires.

Among the various causes of fires which are preventable may be mentioned defective chimneys and flues, sparks on combustible roofs, careless use of matches and cigarets, careless handling and storing of gasoline and kerosene, faulty electric wiring, and improper use of electrical apparatus. Among the major causes of fire which can only be listed as semi-preventable, may be mentioned such natural forces as lightning and spontaneous combustion. It is only these latter causes which interest the scientist to any extent.

In the case of lightning the possibility of fire can be almost wholly eliminated by the proper

use of lightning rods. These rods, which have long been in use, unfortunately acquired a bad reputation which extended over a number of years, because of fraudulent practises or lack of knowledge. Unscrupulous concerns marketed wholly worthless rods which were not built to the necessary specifications and in many instances constituted a menace. In other cases adequate rods were not properly installed, and as a result were worse than useless. The prejudice which was built up against lightning rods has now been largely removed, and rods conforming to the best electrical practises are being installed in many places, with the result of almost perfect protection.

The problem of spontaneous combustion has not, however, been so well solved. The cause of this is still not well understood. It appears that the first step in the cause of spontaneous combustion is often due to bacterial action. But as this ceases, due to the death of the bacterial organisms at about 70 degrees centigrade, which is far below the point of combustion of the substances in which the fires usually occur, it appears that from here on the action must be chemical, and perhaps catalytic.

Because of the enormous number of barn fires that occur on farms through the spontaneous combustion of hay, the Department of Agriculture of the United States has assigned a staff

of scientists to the study of this problem. The best field results that have been obtained so far have come from a study of the Vermont floods in 1927. Many of the farm buildings are in valleys, and during the flood, where barns were not carried away, they were left standing in as much as seventeen feet of water. Fire, under such conditions, would seem to be the last imaginable worry. Yet many fires resulted from just this condition. Hay standing in the barns became wet and, as the dampness favored the bacterial growth, many fires occurred after the waters receded. Barns still standing in several feet of water were burned down to the water's surface.

It appears that hot pockets develop through the action of bacteria. As the temperature rises, secondary chemical reactions set in; these cause air to rise to the surface, and this air, breaking through, creates an upward draft like that of a chimney. The result is a sudden outbreak of intense fire. If the temperature is not raised to the point of ignition it frequently results in charring, and in this way ruining the hay. Similar spontaneous combustion is thought to have been the cause of the destruction of over a million acres of peat bogs in Florida during a single winter.

Man-Made Lightning

The study of lightning, begun by one of the first American scientists, Benjamin Franklin, is now being renewed. The story of Franklin and his kite is a classic, but since his time very little has been done in this fascinating, tho extremely dangerous, field. Perhaps it is the danger which is the cause of this reluctancy to undertake lightning study. At any rate no great advance in our protection against lightning has been made beyond the lightning rod.

In the early days of electric lighting, to have the lights go off was a common experience. It was not difficult in those times to struggle through a half-hour of darkness. The candles were lighted and we did well enough. Now to have the power go off and tie up one of our subways, for example, is a serious thing. Even to stop the elevators in one of our office buildings for that length of time would lead to great inconvenience. Our power must stay on.

One of the greatest causes of interference at the power station is lightning. The methods of protecting the line from lightning are borrowed from the knowledge which has been obtained from lightning rods. In all these years lightning has not been studied first-hand. Realizing this, two of the largest electrical companies in America sent expeditions into the field in the summer

of 1928 to study lightning. The results were far from encouraging. One of these expeditions, which planned to study the effects by photographs taken on an instrument known as an oscillograph, obtained but a single picture in the entire season. This picture was taken in but one fifty-thousandth of a second, and figuring the expense of the expedition, cost $75,000. As a result of this and similar disappointments, a new method of studying the problem has been devised. We now use artificial lightning.

We all remember that Steinmetz succeeded in making artificial lightning in the laboratory several years ago. Since that time the voltages possible in the laboratory have steadily grown. The California Institute of Technology at one time had the highest voltage available in the world—1,500,000 volts. This was recently greatly exceeded at the Pittsfield laboratory of the General Electric Company, where a voltage of 3,600,000 was obtained. The next step was taken at the Carnegie Institute of Washington, where, by the use of a Tesla coil, scientists reached a voltage of over 5,000,000 volts, a value which was again exceeded somewhat by the Pittsfield laboratory.

Now these voltages have been taken out of the laboratory for experimental work on the protection of electrical transmission lines. These lines are struck with man-made lightning and the effects observed in order that better methods of

protection may be devised. The means of protection thus devised are in turn put to the test of being struck by lightning at our own convenience. We no longer have to spend long and useless hours in the field waiting for a chance bolt of lightning to come our way. We have mastered the lightning.

With these high voltages scientists have the hope of obtaining much information concerning the structure of the atom, and it is also anticipated that x-ray pictures may be taken through an entire building, so powerful would be the rays produced by such a voltage. It is expected that such x-rays would reveal flaws in castings many feet thick, whereas now we can penetrate but a few inches. We shall not only be able to defy the lightning by new protective devices; we shall be able to enslave it for our own uses.

VII

ELECTRICAL SLAVES

Robots that See, Hear, Taste, Smell, Feel, Think, and Talk

THE number of robots which have been introduced, as the result of recent scientific discoveries, has been large. It has always been the desire of man to cast off as much of his work as possible on somebody else's back, and the robot is a particularly desirable victim. One does not have to regard his feelings in the matter. But while robots have but recently been made in a form to resemble in appearance that which we think a robot should have—a sort of squared-off human form—they have nevertheless been with us for some time. Glass-blowing machines, knitting machines, etc., show almost human intelligence. They seem to have brains, even tho they are decidedly one-track brains.

But before we can say that we actually have a robot we must have one which can see, hear, taste, smell, feel, think, and talk. It must exercise judgment. As a matter of fact, we now have robots which will do all these things, altho not all are combined in one robot. Only recently has the robot been given an eye—in the form of a

photoelectric cell, a device which changes light signals to electrical ones. This enables the robot to do a great many things. It enables him to measure and match colors more perfectly than can the human eye, it enables him to direct traffic, to count the number of people passing through a gate. The robot so equipped can do all sorts of things in which a difference in color, the cutting off of a light beam, or the production of a shadow, may be made to figure. It can time race-horses, for example, when they are made to intercept a light beam at the finish of the race.

In the matter of hearing, wonders have been accomplished. A robot has been made which in answer to whistles of different pitch can do a great number of things. The thing which is done, of the several possible, is selected by the tone of the whistle. After the job has been done, this robot reports back that such is the case. This particular robot has even been made to answer and take its orders over the telephone. It is called up in exactly the same manner as one calls a person, from any telephone station anywhere. Another robot which has been devised answers to our own language, apparently. In fact, however, it is only influenced by the number of syllables. On one syllable, one impulse, it will perform one duty; on two impulses another, and so on. Thus we have robots that can both see and hear.

Robots have been devised that have a keen sense of smell. These are used where there is danger of accumulation of poisonous gases, and so keen is their sense that they not only warn of the gas on the slightest approach of danger, but state as well the exact amount of the gas present in a given volume. Robots have also been made with a very sensitive touch. One such, a rail-flaw detector, will not only detect flaws in the rail which are external but it exceeds all possible human ability by detecting flaws in the interior of the rail as well. As it moves along the rail it squirts a bit of white paint on every flaw. In the chemical laboratory, also, robots are used for tasting.

It remains only for the robot to talk and think, and this, too, it has done. A robot has been exhibited which answers questions that are asked it. Automatic vending machines now thank the purchaser. In the matter of thinking—the exercise of judgment—we have the case of the traffic robot that is used where there is little side-road traffic. It interrupts traffic on the main road with a red light whenever a vehicle approaches from the side. But should the side-road traffic become heavy, it ceases to function in this manner and throws red and green for equal successive intervals according to the system ordinarily used at crossroads. Whenever the side-road traffic di-

minishes, it will go back to the original method of traffic direction after a suitable interval.

Thus we have robots which will perform almost any duty ordinarily required of man. And these robots can, in almost every case, do the work better than man himself. So far all these abilities have never been incorporated in a single robot. Perhaps this will never be done. After all, the robot excels in the one thing in which man is weak, monotonous tasks, and for these only a limited ability, requiring at most the use of one or two senses, is necessary.

Robot Locomotive Engineers

With all due respect to the engineers who have made American railroading what it is to-day, who have pulled their trains "through" against adverse conditions, and delivered their passengers and mail on time in spite of the weather, it must be said, nevertheless, that their day is passed. So far as driving the engine is concerned, the engineer is now reduced to a mere automaton himself, and other and numerous automatons do the work he used to do. Bear in mind, however, that we do not refer to him as unnecessary. With the complicated high-power engines which we have to-day he must be a more highly trained man than ever. It is his job to see that this immense power plant on wheels functions properly. But the thrill of driving the engine is

over. In a few more years, to all purposes, he might as well be operating a stationary power plant so far as he will be concerned. This is due to the automatic train control that has been introduced.

In a typical automatic system there may be three kinds of blocks. In the first, where full speed ahead can be maintained, the maximum speed may be sixty-five miles an hour for passenger trains, and fifty for freight. If a train exceeds this speed, a whistle sounds in the cab and the brakes automatically set. They cannot be released until the proper speed is reached. This is accomplished by a governor, which is rotated through gears to the wheels. It is like the old steam-engine governor. As it rotates, two balls are thrown farther and farther apart, at the same time pulling up a collar on a shaft. When this reaches a certain point the whistle and brake are operated.

The second type of block is the danger zone. Here the maximum speed will be about twenty-five miles an hour. The governor is automatically changed on entering such a zone to take care of this reduction in speed by a method to be described. A danger zone may be such always or may become one because of the presence of another train ahead. In a caution zone the speed must be tapered down from seventy to twenty miles an hour in 3600 feet. A chime whistle

sounds until the lower speed is reached, and if at any time the engineer exceeds the tapered speed a shrill whistle blows and the brakes are set. Every time an engine passes from one zone to another the shrill whistle sounds and must be stopped by pulling down an acknowledging handle. If this is not done in 300 feet the brakes are set.

These various signals and speed changes are set by means of a current of electricity. In a safe section of track the current follows one rail, passes through the axles of the train to the other rail, and back. So long as this goes on a current is induced in a pair of feelers which are held a short distance above the rails in front of the engine. The current is magnified by amplification with radio tubes and holds down the various devices in their operating condition for high speed. If the current is off, as in a danger zone, the various warnings are released. As a broken rail will break the circuit, either this or a burned-out amplifier tube will set the various devices for danger, and the speed must accordingly be reduced.

From this it will be seen that a train might proceed safely with the engineer instructed never to pull the brakes. Unless he must guard against danger at a crossing, it is never necessary for him to do anything but release them after they have been set by the robot which does

the real work. The control is almost entirely out of his hands.

Subway Safety

Perhaps nowhere else has the automatic control of trains reached the stage achieved in the New York subways. Here control is carried to the limit. Every car is crowded underneath with suspended automatic safety devices. In all, fifty-six safety devices are used on the subways. Twenty-two of them are to guard against failure of mechanical or electrical devices. Sixteen guard against human error. The remaining eighteen are alarms to give warning when human, mechanical, or electrical agencies are not functioning properly. In the old days of railroading it was thought necessary to maintain a twenty-minute headway for passenger trains. The subways carry thousands of passengers with less than a minute headway. In rush hours the schedule calls for over thirty trains an hour at Grand Central and Times Square. Allowing for stopping time, it is obvious that the trains must travel close together. One must be pulling into the station as the other leaves. Automatic devices control the speed of the train pulling in in accordance with the speed of the departing train. In ordinary running the train leaves behind it a string of danger signals and a row of levers standing up alongside the rail. If the

motorman runs by a signal an automatic brake is set by one of these levers. The lights change and the levers fall back out of the way automatically when the train is a safe distance on.

The subway is the first railroad to control the loading of passengers automatically. As long as there is any obstruction the automatic doors will not close. A rubber lap on the edge contains two parallel springs. If one of these is pushed against the other it closes an electrical circuit which prevents the door from closing. Once the door is closed, however, it cannot be opened except by the automatic control system which opens them at the stops. It is also arranged that the power to move the train cannot go on until all doors are closed. Thus the motorman proceeds knowing that all doors are closed, that nothing is caught in them, and that no passenger can open them. The system can be greatly interfered with by those not familiar with it, but this rarely happens. The passengers who use the subway have themselves become automatic and slide in and out with little friction. It is usually visitors from out of town who become annoyed and cause delay. One argumentative visitor caused a serious jam on the whole system by delaying a train for half a minute at Times Square during a rush hour. Trains were held back all along the line, the platforms became crowded, and matters did not straighten them-

selves out for hours. This type of delay fortunately rarely happens.

With automatic control of the trains, and of the loading of passengers, the subway is able to carry enormous crowds with very few attendants. It is not improbable that in the future men may be entirely dispensed with and the trains operated altogether by robots. Already they have taken over the important job of collecting the fares.

Speeding Up the Railways

Our railroads are rapidly being electrified, because we are demanding greater and greater speeds. In 1829 when the Rocket, competing against three other locomotives, carried passengers at a speed of from twenty-four to thirty miles an hour, speeds of 100 miles an hour were freely predicted. That was because rail transportation, being more expensive at the time than any other, offered no advantage except in speed. As costs were reduced, high speeds were no longer sought. In America, where the distances were large and the roads had to compete with low-priced canal traffic, speed remained something of a factor for many years. But with the canal traffic out of the way the railroads forgot about speed again. Thus the famous locomotive, 999, which holds the speed record, made its

run in 1893, not a period that we think of as the age of speed.

Now that the airplane has come into use we are again demanding speed. This is shown by the popularity of the crack trains that are being run in increasing numbers. It is shown by the combined railroad-airplane schedules which call for connections between day airplane travel and night train travel. The railroads realize in the airplane a serious long-distance competitor and in the bus a serious short-distance competitor. They must speed up.

Now, speed costs money. As a train travels faster and faster the depreciation of the rolling stock and the upkeep of track both increase rapidly. The wind resistance also goes up, and there is a tremendous loss of power due to radiation from the engine. It is these things which have limited our speed for so long.

In operation it is necessary to offset as many of these as we can. Electrification helps. On electrified roads the power plant is stationary and can be operated more efficiently than a power plant moving at high speeds. At low speeds the moving power plant is more economical, as there are no transmission losses. In the beginning of railroading many were of the opinion that the trains would be drawn by cables pulled by stationary engines. Such cable lines are in use on steep grades, but it now appears that they

will all be superseded by the invisible cables of electricity.

Our speeds are limited somewhat also by our tracks. As it happens, they are about the best that we know how to build economically. Experiments are being tried out with much longer rails to cut down on the number of joints. Other changes are being considered. We may look forward to electrified roads and much greater speeds in the future.

Talking Movies

It needs no herald to tell us that the talking motion picture is here. It is. And it would seem that every communication engineer in the country is hard at work in this new and fascinating field. It requires the highest developments in the art of communication to make these frozen messages and to reproduce them on the screen. Let us review the process.

To begin with, the communication engineer had to call in the acoustical engineer to help him. In general he became an acoustical expert himself. He had to sound-proof the studios so that absolutely no noise entered from without, he had to still the click of the camera and the hiss of the lights previously used in motion-picture photography. All these are genuine problems.

Having achieved silence, which at this stage

is most certainly as golden in the literal sense as silence ever was, the next problem was to "can" the voices of the artists. In the earliest successes the phonograph record was used. In some systems it is still used. The turn-table had to move in exact synchronism with the film, and the two had to move at constant speed to avoid changes of pitch on the record. This was done by using a constant-speed motor and gearing the turn-table for the record directly to the mechanism which moved the film. If this could not be done they were both moved by synchronous motors. A similar system was used in the reproduction of the film and sound. Since the record must be put on the turn-table and started so as to synchronize with the picture, there is a slight difficulty here. It has been found, however, that they can be out of step by a fraction of a second without its being evident to critical observers.

In other systems of talking motion pictures the sound record is placed on the side of the film which carries the picture. It may be of two types: either it is a black strip (white on the positive) of varying width, or it is one of varying intensity. In the first case the sound is made to vary the width of a slit through which light passes to the film. This is accomplished by picking up the sound and changing its variations to electrical variations by means of a microphone, just as it is done in a broadcast studio.

The electrical variations are used to do the mechanical work of opening and closing the shutter, and the light which passes through sets up the photo-chemical action in the material of the film. Thus we have energy in the form of sound, electricity, mechanical action, light, and chemical action all taking place in recording the sound on the film. Where varying intensities are used, the system is much the same except for the omission of the mechanical shutter. The electrical energy is utilized directly to light a small glow-lamp, the intensity of which varies with the current through it. The sound record on the film is a strip whose intensity varies with that of the lamp.

In reproducing the sound a lamp is placed so that its light passes through the sound record and strikes a photoelectric cell. This cell has the ability to change light variations back into electrical variations. These are amplified by methods common to radio receiving sets and made to operate loud-speakers.

The results which have been attained in this field are truly astonishing, and we may feel assured that we are only on the threshold of a great power in education as well as in entertainment.

Television

Television is an accomplished fact. It is now possible for a man to sit in his home and see events which are happening thousands of miles away. It has been done in trans-Atlantic television experiments. Yet, since television is still in the experimental stage, it has so far obtained but little hold on public interest. In one way it is farther along than most people realize, while in another it is less far along. This self-contradiction lies in the fact that while its progress up to the present has been steady, it has now run into difficulties which appear to have no ready solution. In order to understand this let us look into the method used in television in general.

To begin with, a picture is sent bit by bit in such rapid succession that the eye which receives the picture retains the image of the first bit sent up to the time the last bit appears. The process of viewing the picture or scene to be sent is by scanning it with a powerful beam of light which is made to move over it rapidly. The beam moves over the scene in a manner similar to that in which this page is read. You read one line across from left to right, then repeat on the next, and so on. In like manner a picture is scanned; a narrow strip of light moves successively over adjacent strips. This may also be

accomplished by illuminating the entire scene and scanning it by means of a moving lens.

As the light scans the scene, the variations in light and shadow are used to produce a varying current through a photoelectric cell. In this the light variations are changed to electrical variations. The electrical changes can then be amplified and sent out over wires, or broadcast by radio.

When the varying light signals are picked up at the receiving end, they are reconverted from electrical variations to variations in light intensity. They are amplified and sent through a glow-lamp whose intensity varies with the current. This light is spread out on a screen by an inverse scanning process, and so forms the picture viewed.

Some of the mechanical difficulties will be at once evident. It is obvious that the scanning process at the receiving and transmitting ends must be exactly synchronized, otherwise the picture will be greatly distorted. This is accomplished by sending out from the receiving end a synchronizing signal which is picked up and amplified and which automatically keeps the two scanning systems in step. This requires a separate circuit where wires are used, or if two frequencies are used on the same wires, it requires a filter system. In radio television it requires two

wave-bands, one for the picture and one for synchronizing.

Starting the two scanning systems at the same time is not important. Failure to do this merely means that the picture will not be properly centered on the screen, and this can be remedied at once by manual control at the receiving end.

The two limiting factors in the system are the photoelectric cell and the reproducing glow-lamp. For suitable operation, at present, intense light is necessary to affect the cell sufficiently for transmission. Pictures illuminated with bright sunlight have been sent, but in general it requires much more light than this. At the receiving end the glow-lamp cannot have its light spread out over more than a few square inches if it is to be clearly seen. Thus we are limited at both ends, and as yet there appears to be no more suitable apparatus in sight than we now have.

Much experimenting has been done with other devices used to change light variations into electrical ones, but these have all met with failure. As a rule they fail because of lag. The electrical response to the light does not come until after a short lapse of time. This voids their use in television, which requires that the device follow the changes at rates up into the thousands per second.

It is somewhat the same thing which limits the receiving end. The lamp used must follow the electrical changes and vary its intensity at this same rate. The glow-lamp is the only device which will do this. Unfortunately, it has low intensity. In a way this can be overcome by using a large number of glow-lamps to form a screen, and as many as twenty-five thousand have been used in this way on a single screen. Each of these requires a separate circuit, which results in costly and complicated apparatus. This is beyond the practical for ordinary use. Thus we have reached a point beyond which there seems no possibility of going at present. There is no reason why we may not soon have motion pictures by television, however. Here intense lights can be used at the transmitting end, and even tho the viewing screen at the receiving end is not large, it can be seen by those gathered around.

Many interesting things have been done with television. A system has been devised for recording the electrical variations on a wax disk similar to that used on phonographs. This disk can be later "played" and the picture of the original scene reproduced. Colored television has been accomplished by the use of two or more glow-lamps, which have complementary colors. The light from both is thrown on the screen at the same time. Noctovision has been accomplished. This consists in scanning the scene with

invisible light rays which actuate the photoelectric cell in the usual way and produce the image quite as usual at the receiving end.

Man has always wanted to see and hear at a distance. This has been in evidence ever since he first climbed a tree to look afar. The invention of the telescope gave him his first powerful tool with which he might gratify this desire to some extent. Now comes television, which will allow him to look across continents, around corners, and into dark rooms. When this becomes a commercial success it would seem that at least one of his desires will be thoroughly gratified.

Radio By-products

Obviously we cannot pass over the modern developments of science without some mention of radio. And yet the achievements in this field are so well known to every one that there seems to be but little that one can say that would be information even to the least informed on scientific matters. We have all seen radio develop from the days of the nickel coherer, through the crystal stage, and to the modern vacuum tube. The best we can do, then, is to point out a few of the side developments which the average man may have overlooked.

Consider for example the transatlantic telephony that has become a regular part of our

telephone service. This is accomplished by short-wave radio. We may now pick up the receiver in our homes and offices and call over 17,000,000 subscribers in the United States and Europe. When we talk to Europe from the United States the message is carried to the coast, where it is amplified and fed into a broadcast system. By short waves it is carried through the air to England, where it is received by a radio receiver quite different in appearance from those in our homes, but operating on exactly the same principle. Here it is again amplified and fed into the telephone lines.

Wherever there is a small effect, which can be better studied when increased, the methods of radio are employed. It is now common in medical schools to amplify the sound of the heart-beat both for study and for instruction. In this way the human heart can have the sound of its beat so amplified as to rival the noise of the boiler factory.

The methods of magnification which have been developed in radio are also used in the field of television to amplify small changes of light and shadow. They are used to control trains automatically by small current changes in the rails. They are used by the passengers on trains to telephone while the trains are in motion. The signals are broadcast and are picked up by the wires which parallel the tracks.

There is almost no limit to the uses of radio methods. As another example we might cite the use of radio to light the flood-lights of an air-field through the use of an audible signal from an approaching airplane.

Thus the list grows and is being added to almost daily. There are an enormous number of by-products of radio. To find and describe them all in detail would be a task in itself, and no doubt more than a single volume would be required to do it in. We have benefited in many ways not obvious to the radio-broadcast listener.

And while all this has been going on, radio itself has progressed at a tremendous rate. It is a long way from the head sets of a few years ago to the full-volume, life-like reproduction of to-day, which power amplification and improved loud-speakers have given us.

Rivaling the Sun

The general feeling seems to prevail that we have about reached perfection in the science of lighting. We have been able to build tiny lamps no bigger than a grain of wheat. We have been able to make great flood-lights whose candle-power is rated in the millions. They have been made so bright that they can actually cast a shadow against the sun, altho we must remember that the sun is some 90,000,000 miles away. Because of such achievements we feel that we have

come a long way from the days of our grandfathers who used a tallow candle, or from the times of our own parents who used kerosene lamps. In truth we have, and yet our lighting is far from what it should be.

It is true that occasionally there may exist a well-lighted place. But such places are the exception. Close up all the windows in your home so that no light can get in from outside. Then, after being out in the sun for a short period, come in and turn on the lights. The inadequacy of your lighting will be apparent. Why do you not improve it? Because of the cost and also because of the glare. If you were to bring up the intensity to that of out-of-doors it would be unpleasant. Thus our present lighting has much room for improvement. The life of the bulbs is too short; they convert only an insignificant fraction of the energy which goes into them into light, and the light is produced in too small an area, which necessitates great brightness and consequent glare. Our lighting is good only as compared to that of our forefathers.

Our greatest hope for the future is to be found in the glow-type lamps which are now being used to a large extent in advertising signs. These lamps have the great advantage of producing the illumination over the whole of their interior. This reduces the brightness for an

equal amount of light, and the glare is diminished. It is also true that these lamps more nearly approach the ideal cold light. For a given amount of energy more light and less heat is produced. But thus far they are less efficient than the ordinary lamp, because of the large electrical leakage due to the high voltage necessary to operate them. This will be overcome by better methods of insulation.

Glow-lamps of this type may be made to operate without any wiring entering the bulb. They will operate through the glass from electrodes on the outside, or they will operate from the changing magnetic field of a coil of wire surrounding them. Thus lamps of this type should eventually be much cheaper to make than are those now in use. They would need merely to be placed between two outside contacts, or in a nest made from a coil of wire. The lamp itself would be as clear as a crystal sphere. There would be no filament to burn out, no base to twist off, no evaporation of a filament to blacken the bulb. None of the things which limit the life of our present lamps would be present.

Recently such a lamp as this, placed on the roof of one of the large electrical laboratories, gave so much light that a newspaper could be read by its aid at a distance of two miles. Why are these lamps, then, not in common use? The answer is, principally, that they have an un-

satisfactory color. The color depends on the gas inside. The amber red lamps, so common in advertising signs, contain neon. This gas is chosen because the color stands out well. The blue signs contain mercury vapor. Other colors are due to a mixture of gases or sometimes to the kind of glass used. But thus far a color satisfactory for lighting purposes has not been obtained. Perhaps eventually someone will find the right combination of gases or some other means of making such lamps suitable for home use. Then we may expect to see them come into general use. Because of the red light, given by neon, these lamps are coming into use for signaling, particularly in aeronautics. The red light has a greater fog penetration than equal intensities of white light or light of other colors.

Flood-lighting is another type of illumination that is proving popular. Buildings are flood-lighted for advertising or exhibition purposes. Private gardens are being flood-lighted with a soft glow, with spot lights to pick out any particularly beautiful shrub, or group of flowers. Flood-lighting of air-fields is particularly well developed. The ground can now be flooded with light by a single searchlight that will give sufficient illumination for landing as much as three-quarters of a mile from the lamp. The light is spread out into a fan-shape so that none of it is over two feet above the ground. An

aviator can fly directly toward such a lamp without being troubled by the glare.

Better and better lighting is becoming prevalent everywhere. It has been found in factories that good lighting not only protects the eyesight and makes happier and steadier workers, but likewise greatly increases the quantity and quality of their output. Few manufacturers have to be persuaded nowadays to bring their lighting up to standard for the sake of the employees. They know that they will be well repaid in output for what may be spent. Nor do the employees resent being speeded up in this way. Not only are they quite unaware that they are able to work faster, but they would be happy to do so if it were pointed out to them. No longer is there the knitting of brows over close work and the after-hours headache. It is one way in which every one benefits.

VIII

POWER

Fuelless Motors

THE public has long since ceased to buy gold bricks. It is some time since the Brooklyn Bridge has been sold. No one will consider for a moment investing in a perpetual motion machine. But men, nevertheless, can still be fooled by the very same thing under its new name—fuelless motor. There is no such thing as a fuelless motor and there never will be, in the proper sense of the word. This statement rests on two laws which are known as the first and second laws of thermodynamics. The first of these says that energy can neither be created nor destroyed, and the second one says that you cannot get energy by a transfer of heat from a cold to a hotter body.

If you ask how we know that these laws are true, the answer is that no violation of them has ever been observed by man. You will undoubtedly admit that you are convinced that a stone will never, of its own accord, start rolling up hill. This is because you are familiar with stones. Those who are familiar with the laws of thermodynamics, through years of association with devices depending upon them for operation, are just as sure that a perpetual-motion

machine, or in other words a fuelless motor, will never be built.

Perhaps the nearest approximation to free energy we shall ever get is in the waterfall. It is free in the sense that it flows whether we put our turbines there or not. It costs us nothing to get the water to the top of the falls, and its fall produces power. In the same way winds may be said to be sources of free energy. The wind blows whether our windmill is there to make use of it or not. If we are ever able directly to utilize the rays of the sun, we shall have a similar condition.

The only other forces that we have available are the ocean tides and waves (which will be dealt with separately), the earth's changing magnetic field, atmospheric electricity, temperature differences on the earth and in the ocean. In the case of changes of the magnetic field of the earth we have a factor that is negligible except during the relatively rare period of a magnetic storm. Normally the field changes too slowly to produce any power. This has been, nevertheless, the source of many claims by fraudulent inventors. In the case of the atmospheric electricity we have also a source of power which is negligible. It has been estimated that if all the atmospheric electricity over the State of Wisconsin could be collected it would produce, on the average, but twenty kilowatts of power.

There is as yet no way in which it appears that we shall ever be able to use atomic energy. And yet the stores here are enormous. Dr. W. F. G. Swann, in speaking before the Franklin Institute of Philadelphia, said: "There is so much positive and negative electricity in a cubic centimeter of matter in the substance of the earth, for example, that if all the positive electrons in one cubic centimeter could be collected at one point and all the negative electrons in that cubic centimeter could be collected at another point one centimeter away, the two would attract each other with a force equivalent to 100,000,000,000,000,000,000 tons." Here is room for the imagination to have full play. It is a source which we cannot as yet feel thoroughly assured is not open to us. The prospects for the utilization of atomic forces, however, do not look bright.

Wind-Power

In estimating the power resources of a country, little if any attention is ever given to the wind-power available. We are accustomed to think only of water-power, coal, and petroleum reserves. It is doubtful if a thorough study of the wind resources of even so much as a single locality has ever been made. And yet we know that some localities are regularly affected by

strong winds which, if harnessed, would furnish considerable power.

But rather than increasing our use of wind as a power-source, we have been tending in the other direction. Sailing vessels have all but disappeared from our seas. In Holland, the land of the windmill, we are told that electric motors are being installed in their place. Recently a rotor-ship, using the power from the wind in a novel way, was admitted to be a failure after many tests. The wind as a source of power has fallen to a negligible use.

And yet we all know that a sheet of canvas on a boat, with even a moderate breeze, will do the work of a two or three horse-power motor. We know that the farmer uses the windmill to pump water for his animals. This is a heavy duty. Where, then, is the trouble? The answer is in the lack of dependability. The necessity is for an engine which is not dependent on the whims of the weather. It causes too many delays and too much loss of man-time, which is expensive.

In the case of pumping water the windmill does well enough, for it can fill a tank that will last over a calm. This is what is needed if we are to use a windmill for power, a system whereby power can be stored to be used when there is no wind. This could be effected by impounding water on a hillside, where the contour

of the land made it possible, or by accumulating electricity in storage batteries. This latter system is no different from that in use on hundreds of farms to store the energy from a gasoline engine for farm lighting. Recently the Air Service has adopted a similar scheme for the purpose of operating signal lights in out-of-the-way mountain regions. The whole device functions automatically. Whenever there is a suitable wind the batteries are charged by the windmill through a generator, and at night the beacon lights are turned on automatically. These lights will function without attention for six months at a time. The only occasion for visiting them at these intervals is to put more water in the storage battery. It is even conceivable that this will also be made unnecessary, the water being provided by rain and allowed to run into the batteries under the control of a float.

At the present time there appears to be a possibility of improving the efficiency of windmills by borrowing from the researches in aeronautics. It would seem that there might be obtained valuable information on the most effective shape for the blades as well as the angles at which they should be held. Also there is no doubt that if we abandoned the idea of directly coupling the wind-power to the machine to be driven, the windmill could be more advantageously located than at present, perhaps on a

hill-top, and the power brought to a point where needed, electrically.

There is no doubt that here is an enormous energy reservoir which is going to waste principally because of its lack of reliability. When some convenient and cheap method is devised to compensate for this, the wind, as a source of power, will doubtless come back into favor.

Harnessing the Ocean

Harnessing tides is an ambitious project; and thus far it has not been done. That it will be done in the near future, at least in one case, seems certain. In Passamaquoddy Bay there is a rise and fall of the tide over a range of about twenty-eight feet. The bay, which lies between the province of New Brunswick, Canada, and the State of Maine in the United States, has across it a row of islands and shoals. It is planned to build a dam across this, which would impound the water at high tide and release it later through suitable gates for the generation of power. The cost of developing this project to produce between 400,000 and 500,000 horse-power is estimated at $50,000,000 to $75,000,000. It is thought that eventually as much as 800,000 horse-power could be developed.

In this instance there exists a particularly favorable set of circumstances. Not only is the tide high, but the district is such that uses for

this power could be easily developed. The formation of the bay is likewise favorable. There are many other places where the tide is favorable, but something else is usually lacking. Thus at Anchorage, Alaska, the tide is higher than at Passamaquoddy Bay, but no market for the power could be obtained there.

As one sees the rise and fall of a ship with the changing tides one cannot but be impressed with the immense power at work. The difficulty in utilizing this power is one of storage. If we required power only as the tide went out, all would be well, but when power is needed at all times and can be generated only with the fall of the tide, a storage system is essential. At Passamaquoddy Bay this can be taken care of by impounding the water, but not everywhere is the land formation favorable to this. Other systems of storage have been found uneconomical.

In addition to the tides it has been suggested that the battering action of the ocean's waves be harnessed. Commander Lybrandt Smith of the United States Navy has invented a system whereby each wave enters a funnel and by its battering action forces some of the water up into a pipe at the funnel-end. It is prevented from returning by suitable valves. In this way water is raised to a higher level and the energy due to its fall utilized.

When not all of our natural waterfalls have

as yet been developed, and when the cost of power-development by natural falls is approximately the same as generation by coal, Commander Smith's suggestion would hardly seem practical. Added to the usual costs there would be the cost of the installation to raise the water.

In the same way the suggestion of use of the ocean's currents is not feasible. These are no swifter than our inland streams, and the power which could be obtained from their flow would be negligible.

An interesting scheme, which appears to have some promise of practicability, is that of the French scientist and inventor, Georges Claude. M. Claude proposes to use the difference between the temperatures of the ocean surface and the ocean depths. The temperature at a depth of 3000 feet is thirty-five or forty degrees lower than that at the surface. For more than a year M. Claude has had a small experimental plant operating on the Meuse River at a point where the temperature difference between the top and bottom is about forty-six degrees. Water at the lower temperature is pumped through a pipe insulated against heat. He estimates that the rise in temperature of the water brought up from below will be about one degree because of heat-leakage through the pipe.

Recently the plant on the Meuse, which generates fifty kilowatts of energy, has been moved

and is to be set up sixty-two miles east of Havana. Here a long corrugated metal pipe will run out to sea and to the ocean's bottom. It is felt that this is a nearly ideal place to try out the experiment, as the system lends itself primarily to the generation of power in the tropics and especially on the tropical islands out at sea. If this station proves successful, M. Claude visualizes, first, a series of such power stations to generate about 15,000 horse-power each, and ultimately, stations of as much as 150,000 horse-power.

Heat from Cold

Somewhat similar, and yet half as far apart as the poles, is the suggestion of Dr. H. Barjot as compared to that of M. Claude. Instead of utilizing temperature differences of the ocean, Dr. Barjot proposes to utilize the temperature difference between the atmosphere and water protected by a surface of ice. Thus while M. Claude's plan is adapted to the tropics, that of Dr. Barjot is suited to the arctic regions.

Ordinarily we use coal to produce steam, and cold water to condense the steam, which is used over again. According to Dr. Barjot's plan we would use the heat of the water under the ice to vaporize a substance, such as a hydrocarbon, and this would be condensed by frozen brine. Some material such as propane, butane, or petro-

Tuscany, Italy. Here there is a valley which seeps with hot springs and steam coming from the ground. About twenty years ago Prince Ginori Couti conceived the idea of utilizing this steam as a direct source of power. He piped it into the cylinder of an engine which he succeeded in running, and which has been in use ever since.

A few years ago Mr. J. D. Grant, who knew nothing of the Italian venture, took a lease on a piece of property in California, strikingly similar to that in Italy, and began to develop steam wells for power purposes. Had he been familiar with the Italian case he would doubtless have been discouraged, for the temperatures and pressures at the ground-level were less in the California area than in Tuscany.

Mr. Grant developed one of these wells by boring in a manner somewhat similar to that used in oil-well construction, and as the temperature and pressures of the steam increased with depth he was able to develop a steam well which operated a small turbine and supplied a neighboring hotel with light and power. Using the power available from the first well, he has subsequently drilled five others, which vary in depth from 500 to 650 feet. The temperature in these wells, when they are closed, has been found to vary from 290 to 374 degrees Fahrenheit. As this is considerably above the boiling point, we

have a superheated steam. This is a great advantage in power generation. The pressure in the wells was found to vary from 60 pounds per square inch to 275 pounds per square inch. The output of steam is from 1,500 to 52,000 pounds per hour. There seems to be no diminution of the capacity of these wells to produce power over the time they have been in existence.

While wells of this type are not at all likely to become an important source of power, they offer an opportunity for interesting speculation. Mr. E. T. Allen, who has investigated these wells under the auspices of the Carnegie Institution, writes:

> The existence of such an underground reservoir supplying amounts of steam of this magnitude is not only at variance with the known facts of geology; it is also opposed to the semi-arid climate of the region and its scanty store of ground water. The steam must take its rise in a deep-seated source, since its pressure and temperature and the magnitude of the flow increase with the depth of the well. It may be said that the evidence shows that the steam originates in a great mass of molten or partially fluid rock, similar to molten lava in its properties, buried at an unknown depth in the crust of the earth. One reason for this conclusion is that all types of igneous rock, when heated to redness, give out large volumes of steam that is always associated with small amounts of gases as natural as steam is.

Thus, whether these wells ever become of commercial significance or not, they have at least added to our knowledge of geology. Perhaps it will be the inspiration from them which will eventually cause someone to risk the fabulous sums necessary to reach commercially valuable temperatures by straight boring—if we do not in the meantime reach these temperatures through our oil wells, which are of ever-increasing depth. The center of the earth may be our ultimate great power source.

Rockets for Motive Power

The use of rockets for motive power has long been scorned. And there are those who, in spite of the recent decided successes, still treat the subject of rocket propulsions lightly. In fact, they do not admit that the recent experiments with rockets were successes, but rather feel that they have proved the impracticability of rockets for propulsive purposes.

The experiments with the automobile known as the Opel, not long ago, which finally led to the complete demolition of the vehicle by explosion, are not taken seriously. The use of the rocket sled on Lake Starnberg by Max Valier, however, led to considerable success. He reached speeds with this sled of approximately 249 miles an hour; and yet his work received scant notice. The sled did its work so easily that there was

apparently nothing spectacular to report. The rocket which was sent off by Prof. Albert H. Goodard in the summer of 1929 was considered by many as a great joke, a complete dud. Nevertheless, it apparently did exactly what Prof. Goddard expected it to do. It careened through the air with great noise and landed a quarter of a mile away. It was neither a failure nor the climax of many years of experiment. He was trying out a new liquid explosive and no doubt gained considerable information from this experiment. More recently we have learned of a successful flight over a short distance, in Germany, by a rocket-driven airplane.

Whatever the critics of this mode of propulsion may say, the fact remains that rockets actually have driven various kinds of vehicles over short distances. And it should be kept in mind that not only is the mode of operation at the present time crude in its development but that also it has been applied to vehicles designed for other types of power plant. We have as yet not even begun to change the design to suit the power used. The critics should also take time to recall that there are still many of their kind living who said that an airplane was an impossibility. They now must listen to the drone of the motors of airplanes daily. And it should be remembered, too, that their criticism was much more justified than is that of the rocket critics.

The airplane was something much newer and more revolutionary than is the rocket.

If we look back into history we find that Hero of Alexandria is said to have invented an engine on the rocket principle, 2000 years ago. This was simply a large metal sphere with two bent spouts. The sphere was arranged so that it could rotate. When water in the sphere was boiled the steam escaping from the nozzles caused the sphere to be set in motion. No less a person than Sir Isaac Newton invented a steam engine which was to move by the reaction of steam shooting from an exhaust in the rear. And, as a matter of fact, this is exactly the idea used in our steam turbines to-day. The rotor moves because of the reaction of steam against blades.

One of the great advantages of the rocket is that it does not require a material medium in order to move. A ship moves because of the reaction of its propeller against the water. In the same way an airplane pushes against the air. But in the case of the rocket the motion is the direct reaction against the gases expelled. Thus a rocket will move through space completely devoid of all matter. Because of this fact, those who would visit the moon or other planets have always based their hopes upon it, and it is this which has given the rocket a bad start. Those who work with it are usually looked upon as

visionaries bent upon some interstellar voyage. This has kept many serious people, who did not wish to lose their friends, out of the field.

Whether we reach the moon or not, it is true that we should be able to reach much higher points in our atmosphere, by the use of such rocket-propelled airships, than we have heretofore. The height which a dirigible can reach is very limited because of the decrease in lifting power as the atmosphere becomes more rare. The height which an airplane can reach is limited by the lessening efficiency of the propeller against the thin atmosphere, by the loss of buoyancy, and by the freezing up of engine parts at the high, cold altitudes. As the rocket goes higher it has the tremendous advantage that the air resistance is reduced without loss of power. At great heights in the atmosphere it should be theoretically possible to travel by rockets at enormous speeds with very little expenditure of power.

We may confidently expect to see considerable advance in the use of rockets in the near future. The one thing which acts as a detriment to their use at the present time is the lack of methods of controlling the combustion. When this is solved, the rocket as a motive power has a clear road ahead.

Diesel Engines

In 1921 only 330 Diesel engines were built in the United States. By 1925 the number built in a year had reached 4101. What it will be for 1930 or 1940 no one can tell, but it is safe to say that it will be many times this figure. The Diesel engine is gaining ground at a tremendous rate, and the number of uses to which it is being put is also on the increase. Mr. Julius Kuttner, oil-engine expert, writes:

> Some of the output finds its way into the pumping stations of oil transport lines, while the remainder is applied to industrial uses too numerous to mention and to the propulsion of boats and ships. There are now thirty-five Diesel-engine-driven railroad locomotives in the United States, and one airplane. The one-hundred-passenger British airship R-100 will be propelled by five Diesel engines. More ships are now being built with Diesel engines to propel them than vessels with steam power.

What is the cause of this rapid rise in the use of Diesel engines? The answer is in their efficiency. Using the highest compression possible in the gasoline engine, the efficiency has not been raised much above twenty-five per cent. This means using the highest-grade fuel and having the entire engine operating under the most favorable conditions. Steam engines do not exceed twenty per cent. efficiency and usually run

somewhat below this. Diesel engines regularly attain an efficiency of thirty per cent. using only low-grade furnace oil. That is the secret of their popularity.

This high efficiency is due to the method of applying the fuel. The oil is not mixed with air before going into the cylinders, as in the gasoline engine. The air is injected into the cylinder free from fuel, and is there compressed to about eight times the pressure used in gasoline engines. Then the fuel is injected and is burned because of the high temperature to which the air has been raised by compression. In such a system there is no danger of preignition, from the high temperature of compression, with the consequent knocking, which takes place in the gasoline engines. It is because of this that the high pressures and consequent efficiencies are possible. Also it is to be noticed that the electrical ignition system is completely done away with. This avoids any possible failure from that source and adds greatly to the reliability of operation.

In the past much effort has been directed toward making these engines in sizes small enough for truck operation. Because of the necessity for outside-pressure apparatus, and because of the weight per horse-power needed where such high compressions are used, they have been too heavy for trucks. Now, however, we have Diesel-

driven airplanes. The Diesel used in this case weighs less than three pounds per horse-power. The reduction has been accomplished by firing the charge nearly on dead center. In this respect the design flies in the face of previous engineering opinion; for it was thought that the weight would have to be greatly increased to take care of the tremendous strain which would result from so firing the charge. This has not been the case. Thus we have the first flying Diesel. The advantage of such an engine is decided. It gives a twenty per cent. increase in flying range, abolishes all ignition dangers due to the failure of the electrical system, removes the fire hazard of the gasoline, and ends electrical interference with radio signals.

There is a possibility that eventually the Diesel will completely replace our present gasoline engines and most of our small steam plants.

The Trend in Railroad Locomotives

Perhaps the casual observer would say that there have been but few changes in railroad engines since he was a boy. Possibly they are bigger to-day, but that is about all that he sees. As a matter of fact, there have been such great changes in locomotives in the last ten years that any engine older than this must be considered obsolete.

The railroads, with a fixed price set on their

services and the cost of labor and materials advanced, must operate economically. No longer can an engine be gradually shoved from one type of service to another, finally reaching the branch lines of the road as its age increases. To make a profit on the branch line it is now necessary to use an engine designed for its own particular work; each one is a tailored job. It will be efficient on one particular job, but may be far from efficient on others. This accounts for the enormous expenditures that are being made by the railroads for locomotives. One road bought fifty new engines in a single year, to be used entirely to draw its fast passenger trains. These cost about $90,000 each, or a total of nearly $5,000,000. They maintain the schedules with greater speed and economy. The old engines were doing the job, but the decreased cost of operation of the new ones is apparently great enough to offset the original expense.

In 1905 the heaviest engine purchased weighed 355,000 pounds and had a traction of 71,600 pounds. In 1915 these figures were 485,000 and 103,000 pounds respectively. By 1925 the weight had increased to 594,940 pounds and the tractive power to 127,500 pounds. This means more than is evident on the face of it. There is not only the question of increased efficiency of the engine to be considered, but the railroad engineer must ask himself many other

questions. Will our present rails and road-bed carry this engine? What will it do to the cost of the upkeep of the road-bed? Will it be necessary to strengthen our bridges, to increase the clearance of our tunnels, to lengthen our turntables? There are all these and many similar questions to be gone into.

The process, then, is somewhat like this: The locomotive builder is asked to draw up preliminary plans for an engine of a certain weight and power, to be used in a class of service for which it is evident that an engine of that type would be efficient. When these plans are in hand, the entire road must be gone over to find what new problems this engine will introduce. If it appears that they can be made at a reasonable cost, then the plans for the engine are worked out in greater detail by a joint committee of engineers representing the railroad and the builder. Every operating feature of the engine will be known before it is built, and its total weight will also be accurately determined. While it is being built the necessary changes on the railroad are being made.

The future of the railroad also must be considered—the possibilities of future electrification, the possibilities of elimination of grades, the possibilities of relocating part of the line. Every precaution must be taken to guard against the possibility of the engine becoming obsolete

because of changes in the road itself or because of changes in competing lines. These are the things which guide the evolution of the locomotive.

Our Power Resources

It is estimated that only four per cent. of the power used in the United States comes from water-power, that the soil yields six per cent. in firewood and three per cent. in power from farm animals. This accounts, altogether, for thirteen per cent. of the power used. Neglecting minor sources of power, such as the wind, this means that the other eighty-seven per cent. must come from the consumption of irreplaceable natural resources, coal and oil.

For many years past we have heard a cry of diminishing oil resources. Mr. Thomas Reid, writing in *Mining and Metallurgy*, said: "As long as I can remember I have been hearing that our petroleum resources were in imminent danger of speedy exhaustion, and yet the yearly output is now of the same order of magnitude as the total resources were once estimated, with the cry of overproduction the loudest it has ever been. Tapping ever progressively deeper and deeper sources of supply has produced this result." To this factor must also be added the new methods of prospecting by sound, radio, etc.

But of course, you say, this cannot go on;

there must be a depth beyond which we shall find it impossible to drill. Discounting the possibility of finding commercial temperatures at these depths—that is, of obtaining power direct from the heat of the earth—we still have little cause for worry. We have already found a method of getting gasoline from our coal mines through the hydrogenation of coal. It is generally agreed that our coal resources will last us for centuries hence. By that time we may have devised a method of getting energy direct from the sun. Future generations may laugh at our laborious method of digging coal out of the ground and transporting it for miles, when clean sunshine is right at our doors, if we but knew how to use it.

Plants are another source of fuel, which must not be overlooked. We may be able to grow a new crop of fuel for engines each year, just as we used to grow a new crop of fuel for animal power. Alcohol can be made from any plants by fermentation, and internal-combustion engines to burn alcohol have been available for some time. At present there is little incentive to use such engines because of the higher cost of the fuel required for them. In some of the sugar-raising countries, however, where quantities of molasses are available from which alcohol can be readily made, one notes a definite attempt to encourage the use of this fuel through import taxes

on gasoline and on gasoline-burning motors. This may lead to great improvements in alcohol engines.

The introduction of the Diesel engine, which can use a much greater proportion of the fuel taken from oil wells, will also tend to prolong the life of our petroleum resources. Not only will the Diesel operate on low-grade fuel, but at the same time its efficiency is considerably above that of the gasoline motor.

With the improved methods of pumping oil many old wells are again producing as heavily as they did in the so-called golden days.

All these things are working in our favor, and while, for the sake of decrcased cost to ourselves, it is desirable to use these natural products with all possible efficiency, it does not seem that their conservation for future generations is at all necessary. The wants of the future generations, indeed, are quite obscure to us. If we denied ourselves the use of natural resources for their sake, we should be like the miser who ate only rotten apples all his life, refusing to use one that might keep for another day.

IX

PUTTING WAVES TO WORK

Secret Signaling

A FAVORITE use of light waves has been for secret signaling. For this purpose we have at hand a great variety of radiations, starting with radio and going on down to the short waves of the x-ray. Most of these radiations, however, are wholly unsuited for secret communication. The radio offers little privacy, and radiation in the ultra-violet, and on down to the x-radiation, is too readily absorbed by the air to be of any service. This limits us to the visible and to the infra-red. Of these two possibilities the latter has been a great favorite, since besides the quality of invisibility it has the additional advantage of passing very readily through fogs. The question then becomes one of detection. Since it has a considerable heat effect, this has been used as a means of detection. Instruments can be made so sensitive as to be used to measure the heat from the most distant stars. In signaling they are of little use, however, as it is the changes which must be measured, and these occur too rapidly in useful signaling for such devices to follow. The most useful thing so far found has been the

red-sensitive crystal. Molybdenite is one of these. It has the characteristic of producing an electrical current when the rays strike it. The chief difficulty is that the crystals become fatigued on exposure, their sensitivity rapidly falling off beyond the point of usefulness.

In the end we are driven back to the use of visible rays for the purpose of secret signaling. We find that the best method is to use a light beam in which changes can be made which those not properly equipped cannot detect. Thus one method is to use a bright light and send our signals by placing before it, at the proper code intervals, a thin gelatin film of the type used to filter out the red in photography. This produces a change of intensity so slight that it cannot be detected with the naked eye. If, however, one is supplied with a deep-blue filter, principally transparent to the violet, and views the light through this, interposition of the red filter produces near darkness and the signals can be read with ease. Since the number of possible filter combinations is very large, one has a fair chance to escape detection by even the most persistent inquisitor.

Polarized light has also been used in signaling. Normally light is thought of as vibrating in all planes at right angles to the direction of the beam. The directions of vibrations might be likened to the directions indicated by the bits

of tinsel on a string of Christmas tinsel, the length of the tinsel representing the direction of the light ray. If we were to take an iron and press this tinsel flat, that would represent one kind of polarized light. It would be plane polarized. It is possible also to produce circularly or elliptically polarized light. Detection of changes in polarization depend upon knowing what changes to expect and being provided with suitable apparatus to detect them. This then becomes a method of secret signaling.

Another method is found in the use of very restricted beams. Such beams can best be produced by placing a small lamp, such as a flashlight, at the focus of a telescope, and burning it at overvoltage to produce great brightness. A large lamp is undesirable, as only a small part of the filament can be at the focus in any case, and the rest may give light that spreads. When properly arranged, a beam only a few feet wide, will be produced even at a distance of many miles. Unless an individual is directly in the beam he can see nothing. In use the sender, looking through the telescope, focuses it on some predetermined object, such as a particular pane in a window. The individual at the receiving ends looks for it at that spot. All is then in readiness to send a code message by interposing a screen.

Colored Motion Pictures

Color photography dates back to 1861. It was at that date that Clerk Maxwell first exhibited a colored picture before the Royal Institution. His method was based upon the fact that white light can be split up into three primary colors —green, blue, and red. When these are combined, white light is produced. Maxwell took three pictures of the same object, one through a filter of green liquid, another through a red, and a third through a blue filter. He projected all three of these, superimposed, upon a screen. The result was a picture colored approximately like the original. This is difficult to accomplish with any fidelity, because of the difference in sensitivity of the photographic plates to different colors. It required exposures of different lengths. At present, however, plates are made which are of nearly equal sensitivity throughout the spectrum, and cameras have been made which expose the three plates at one time. Motion pictures using this plan require that three films be used and be projected synchronously. This is so difficult of accomplishment that a compromise has been made and but two colors used. In this case they may be put on the opposite sides of the same film.

The first advance on this was to combine the three plates into one by placing before the plate

used a colored filter ruled with the primary colors in very fine lines. In projecting, these lines had to be in the some position relative to the plate as they were when the picture was taken. This was difficult to do, as may be imagined. The difficulty was overcome in the Lumière process. Here the fine ruling was replaced by colored transparent starch-grains which were sprinkled over the plate. These remained on the plate after development, so that they constituted a permanent filter, always in place.

The Lippman process avoids the use of filters altogether, utilizing instead the interference of light waves. It is theoretically a perfect system, but in actual practise is not satisfactory. It suggests a possibility which might be developed in the future, however. In this system the plate used is backed by a mirror surface which turns the light waves back upon themselves. These, since they interfere in such a way as to produce standing waves in the emulsion, cause the film to be reduced in layers upon development. When viewed at the proper angle, after development, these striations filter out all but the color which produced them, and we have a colored picture similar to the original scene.

Undoubtedly the most practical system so far devised is that which is now employed in amateur motion-picture systems. This scheme is more nearly analogous to the finely ruled filter than

to any other. A large filter composed of but three large segments of the primary colors is placed before the usual motion-picture camera. This splits the light from every object before the camera into the three colors that make up white light. Now, the film on which this light falls is ribbed like corduroy, the ribs running the length of the film. Each rib constitutes a tiny cylindrical lens running along the film. When the light from the filter reaches these ribs, since each color comes from a slightly different direction, it is focused in a narrow strip on the emulsion side of the film. The emulsion side is opposite the corrugated side and is away from the lens. When the film is developed there will be a series of strips, each of which has been exposed to but one color. These strips will be alternately red, green, and blue, just as if a colored, ruled filter had been placed before the film. Each rib will have produced such a series of three strips.

When the film is projected, the process is the reverse to that described. The light retraces the path it took on exposure. The same filter is used.

While the system would appear ideal, it is still of little value to the professional. One of its greatest drawbacks is that only one copy of the picture is produced, the original, whereas a producer requires several hundred. Also the intensity of light produced is so small as to limit the projection to a small screen suitable only

for amateur use. Perhaps these objections will eventually be overcome and our present colorless motion pictures will become extinct almost overnight, as has the silent picture.

X-rays Now Work Overtime

The x-ray has been of so much value in the hospital that it is thought of almost entirely as a hospital tool. That is where most people come in contact with it. But its use is far more general than we realize. It has found its way into many industrial uses and is constantly pushing the frontier farther back.

The industrial uses of the x-ray are in general very much like its hospital uses—to examine the interior of things which it is not possible or desirable to dissect. Thus it has come to be used for the examination of welded joints, for examining castings for blow-holes or inclusions, and so on. In such cases it is obvious that the x-ray has the advantage over other methods of examination in that the object is not destroyed or injured in any way. During the war the x-ray was used to examine the castings intended for shells. The defective castings were thus sorted out and much time and labor, which would have been used to machine down the defective casting to proper dimensions, was thus saved.

The x-ray has also been used a great deal to examine the condition of assembled objects. Dur-

ing the war, when much wood of inferior grade had to be used in airplane construction, the x-ray was used to find defective gluing, grub holes, or resin pockets. The x-ray has been used to examine the condition of wiring inside the electrically heated jackets worn by aviators, to search bales of cotton for contraband at the customs offices, to determine the location of plumbing in the walls of buildings, to examine the interior of golf balls, and to test the construction of shoes. The list is almost an indefinite one. Any ingenious person can think of many things which could be advantageously examined in this way. He will find that nearly everything up to the equivalent of about three inches of steel has been so examined, and in many cases this is being done as routine inspection.

In addition to this valuable shadowgraph work, the x-ray is being used to study the crystal structure of materials. With its aid the engineer can look inside the actual structure of metals and note their atomic arrangement. He can decide which atomic arrangement gives the greatest strength, greatest hardness, greatest elasticity, and so on. Melting-points and magnetic properties are also dependent upon the atomic structure. These, too, are open to the inspection of the trained metallurgist through the use of the x-ray. He can, in effect, walk around inside the metal and determine its characteristics just as a

bridge engineer might examine the construction of a bridge.

Recently the x-ray has come into use to examine into the authenticity of paintings which are offered to collectors as works of old masters. The pigments used a few centuries ago were mostly of mineral origin and therefore opaque; whereas to-day anilin derivatives are largely used. These newer paints are much more transparent to the x-ray than are those formerly used. The application of the x-ray to the examination of such pictures makes it possible to decide almost certainly as to the probable date of the painting. In this way the ones with fraudulent pretensions are detected, and on the other hand the x-ray has in some cases revealed great value beneath an unpromising exterior. The old master's canvas had merely been painted over for use a second time. The x-ray has now become a permanent part of the equipment of most museums. It is invaluable in the examination of old treasures which could not otherwise be examined without injury.

Such use of x-rays is comparatively recent. X-rays have been so tied up with medical work that their other uses seem to have escaped notice. It is a new field filled with interesting possibilities.

The Photomicrograph—the Police of the Metals

In addition to the frequent use of the x-ray to examine the crystal structure of metals, there has also come into use the photomicrographic method. These two methods are not competitive; they are supplementary, for while the x-ray examines a group of perhaps a score of molecules the photomicrograph takes in the area covered by an enormous number. The use of the x-ray might be likened to the examination of this page, or a single letter on it, with a magnifying glass, whereas, in comparison, the use of the photomicrograph would correspond to the examination of a pile of bricks with the eye. And if we use low-powered magnification on our photomicrograph it corresponds more nearly to reconnoitering a territory with an airplane. Thus there is a place for each of these methods.

In examining a piece of metal with the photomicrograph we are merely taking a greatly magnified picture. The method is to polish off the metal very carefully and then etch it with acid. When examined microscopically, it reveals numerous opaque crystalline forms standing out from it. The first examination is low-powered and gives a general view of that part of the surface. If, on this, there appears anything that looks suspicious, it is examined separately under much greater magnification. We have located our

pile of bricks, so to speak, from the air; we now descend to examine them.

But why should anyone wish to do this? To make better metals for our daily use. The properties of metals depend almost wholly upon crystal structure. This can be varied in many ways, but particularly by heat treatment. Just what this should be is determined by experience. Suppose we find that a metal is weak. We examine it and find a particular crystal structure. It is safe to assume that this particular crystal form is undesirable, and so we shall try to avoid it. Thus we come to know at once the forms which are desirable for different purposes. The so-called weak metal may be weak in tensile strength, but it may stand much bending. Different properties are associated with different crystal structures.

Iron, by itself, is in general rather weak. It is relatively soft, easily bent, and of low tensile strength. But put some carbon with it and it becomes steel. It is harder and much stronger. The same result is accomplished, in a more pronounced fashion, by putting vanadium in the metal. Iron can be made tougher yet softer, or harder and more brittle, by such methods, at will. It can also be made stronger without the brittleness. Its properties can be made almost what we want them to be—within limits. But it requires care. If the carbon put in is not well

distributed, the effect is lost. If the carbon is in a chunk large enough to make up an entire cross-section of a piece of metal, it is obvious that the metal would snap off at this point with the slightest strain. The photomicrographic method tells us how well the distribution has been made. And, knowing the effect on this distribution of various kinds of heat-treatment, the product can be varied at will. The manufacturer now keeps a constant check on his product by this method.

A few years ago it was not at all uncommon to see an automobile by the side of the road with a broken rear axle. Such a thing is never heard of to-day. The manufacturer is no longer guessing as to the strength of this part of his car. He knows that every rear axle he turns out is a good rear axle and exactly like all the others in strength. He knows this from constant tests, tests in which the photomicrograph plays an important part.

Prospecting by Radio

In no field has the introduction of scientific methods brought about more of a revolution than in that of prospecting. The days of the old-fashioned prospector who went along chipping off bits of rock here and there in the hope of a valuable strike are not only numbered, they are actually over. No longer will the hit-and-miss method, so common for years, yield the results

which modern business demands. The lone prospector has given way to tractor-trains and airplanes which disturb alike the stillness of the north in their quest for metals and the dusty plains of the south in the search for more oil.

The methods which are now used in prospecting are the seismographic, the magnetic, the gravitational, and the electric. In the first of these, the seismographic, a large charge of dynamite is buried in the earth and set off. Its effect is measured by a seismograph placed at some distance away. As the time required to travel is an important factor, a modern broadcasting method is used to determine this. Sending equipment is set up near the scene of the explosion, and receiving equipment near the seismograph. When the explosion occurs the signal is at once received at the seismograph end, and the time which elapses from then until the sound has reached the seismograph through the ground is measured. To the experienced this means a great deal concerning the nature of the intervening ground. So important is this method of prospecting believed to be that the government has set aside a special wave-band for this purpose.

The magnetic method is useful principally in the search for magnetic materials, but as all metals have either a greater or a lesser permeability than the surrounding earth, much can be learned of the substructure of the earth by map-

ping the magnetic field of the region. This is done by first making a map and then marking on it, at many locations, the directions in which a magnetic needle points. The marked map, of course, requires interpretation by experts.

The gravitational method requires that we actually weigh the earth. An instrument of extreme sensitivity, called the gravity balance, is used for this purpose. A movable part of the instrument is attracted by the earth beneath it, the degree of attraction depending upon the density of the earth's crust at that point. Inclusions of metal thus affect the instrument. So sensitive is this device that the presence of a person in its vicinity will throw it completely off in its measurements. In use it is set up in a protecting tent or other shelter, to shield it from winds, and is left to make its record photographically. Examination of the resulting photograph can be made at leisure.

The direct electrical method consists in burying in the ground two terminals of a high-potential machine, such as an induction coil. These are buried at some distance apart. Then, by the use of a searching coil, the electrical field at a great many points in the vicinity of these buried terminals is measured. These intensity measurements are plotted out on a map of the region and points of equal intensity joined with a line. The shape and density of these lines on the map

determine the nature and location of deposits which may be underground.

This does not mean that the trained geologist no longer has a place in the search for mineral deposits. He is as valuable as ever. To find a needle in a haystack one must first locate the haystack. Obviously we cannot feel our way over the entire country with the sensitive methods of the geophysical prospector. The geologist must point out first the promising places to look.

Sound Waves and Architecture

One might expect that the study of sound would date back beyond the study of any other physical phenomena. Perhaps it does, and yet the satisfactory application of principles known for years has been accomplished only recently. We do not have to stretch our memories much to remember the squeaky phonographs on which we heard a distorted recording of Caruso. They went into the discard scarcely five years ago. Now, when we hear one of these in the home of some friend who has either become deadened to its scratchings or whose musical ear never existed, we wonder that we did not toss our old machine into the scrap-heap the day after it was purchased. The change has been brought about by an application of acoustical principles.

With this change in our graphophones, and in our radios, has come also a change in the con-

struction of rooms and buildings where sounds are produced for enjoyment. This includes our auditoriums, our broadcast studios, our sound-picture studios.

One of the first phenomena to be dealt with in properly constructing an auditorium or studio is that of reverberation. If one makes a sudden sound in a large vacant room the sound will be found to persist for some seconds. One might produce such a sound by clapping the hands sharply or by dropping a plank. The length of time which the sound persists is known as the period of reverberation. This period should be neither too long nor too short. If it is too long the sound of a voice is confused—one syllable carries over into the next. The speaker is understood with difficulty. If the period of reverberation is too short, the room is said to be dead. There is a hushed sense which is most unpleasant. One finds the room depressing; one is inclined to speak in whispers.

Investigations have been made to determine the most favorable time of reverberation. It is found that when a room is intended for music the period can be longer than when it is intended for speech. It is desirable to have some of the sound of one note carried over into the next. But in speech to have one syllable carried over into the next makes both quite impossible to understand.

Recently there have been perfected a number of sound-absorbing building-materials. With these, whose coefficients of absorption are known, it is possible to construct a building whose period of reverberation may have any desired value. These materials are also useful in blocking off outside noises.

Sometimes in a very large auditorium echoes become a serious problem. Whenever it is possible for a sound to travel from the speaker to the auditor over two paths, which differ from each other in length by seventy-two feet or more, the time-lag of the sound over one path, as compared with the other, is sufficient to cause one syllable to arrive via one path at the same time that another arrives via the alternative path. This is very confusing; but unless the reflected sound coming over the longer path is intensified by focusing from a curved wall, the difficulties arising from this cause are not great. Architects, however, have so frequently made a practise of putting arched domes and curved recesses into our buildings that many bad echoes haunt our auditoriums to-day. Once the fault is built in, it is usually a matter of considerable difficulty and expense to obtain even a partial cure. A complete cure is usually out of the question. With the exercise of a little intelligence it is possible for the architects to have their curves and the audience to enjoy their concerts as well

The reflecting qualities of the walls may be determined by means of calculation and models long before the building is constructed. Yet architects do not seem to be completely disgraced if they neglect such precautions. At least not at present, altho the time is rapidly approaching when an acoustical error will be considered as inexcusable as a structural one.

Sounds We Cannot Hear

Whether or not there can be sounds that one cannot hear is perhaps a question for the pyschologists to consider. That there are waves exactly like those which produce the sensation of sound in our ears, but of a frequency of vibration far beyond the audible, is well known. If not being able to detect them with our ears means that they cannot rightly be called sound, then one can refer to their study as ultrasonics, as is often done. This study began with the sinking of the *Titanic*. It was suggested that these short waves be used to determine the location of rocks, icebergs, derelicts, etc. At that time a complete method was suggested and worked out by the English scientist, Lewis Richardson; but nothing practical came out of it. We lacked sufficiently powerful means, at that time, for producing the ultrasonic waves. Such means, however, have recently become available with the radio. The soundless waves can be produced by

electrostatic transmitters, by electrodynamic oscillators, or by the use of piezo-electric crystals. These crystals have the unusual property of changing their dimensions whenever a voltage is placed across them. By the use of an oscillator, similar to that used in broadcasting, the voltage across such a crystal can be changed as much as 100,000 or even 500,000 times a second. By expanding and contracting, in synchronism with these changes, the crystal produces the ultrasonic vibrations. This method is the one most generally used.

When beams of these short waves are projected to the bottom of the ocean they return almost as if the ocean bottom were a perfect reflector. Since their speed under water is known, the length of time for them to reach the bottom and return gives us a measure of the distance traveled. Hence the depth of the water is measured. One may well ask how these waves are detected on return, since they cannot be heard. It is done by heterodyning. In this method one produces a second sound which is almost of the same frequency as the first. If both enter the ear at the same time, one hears a sound which has a frequency equal to the difference between the two original frequencies. In this way they are rendered detectable by the ear alone. Such waves in the sonic depth-finder render useful service daily. This method of depth-finding has a great

advantage over the usual lead plummet in that it can be employed continuously while a vessel is in motion. It will also detect the presence of icebergs, submarines, and so on. More recent devices give a constant visible record.

Ultrasonic waves can also be used for underwater signaling by the dot-dash system, or the voice may be impressed on these waves much as it is impressed on broadcast-carrier waves. Thus these waves may be employed as carriers for an underwater telephone system.

A peculiar property of these waves is their ability to kill fish and small undersea life. Just why they are capable of doing this is not as yet well understood, but the general opinion among biologists is that the waves disrupt the cells. As these waves have been described as very rapid and slight squeezes and tensions in the propagating body, this theory seems tenable. Such waves will also cause explosive materials to explode, and as such materials are exploded by compressions, it would appear that this view is further justified.

Ultrasonic waves might be of considerable service in the field of chemistry. They have great ability to fractionate materials and produce emulsions. In this way emulsions of mercury and of oil in water have been made. Their ability in this direction is so great that they will even split off particles of glass from the sides of a

vessel containing water under which the waves are produced. Small particles of glass will be found floating about in the water.

If a tapered needle-like glass rod has its end dipped in a vessel of oil in which supersonic waves exist, the oil will climb up the rod and be given off its end as a mist. If one touches the end of the rod with the finger the finger will be burned.

An ultrasonic beam can be used under water as a guide to ships. Any vessel suitably equipped can pick up the beam and follow it safely past obstacles. It also enables vessels to communicate with shore or with other ships. It is limited in its use to straight channels, however. It is interesting to note that frequent trouble is encountered near shore from the supersonic waves produced by the rubbing together of pebbles. Computation shows that they should be expected to produce these sounds. Another noisy member of the ocean's bottom is the hitherto unsuspected clam. It is found that from the supersonic viewpoint he is a very noisy animal indeed. He constitutes a nuisance in ultrasonic measurements near shore.

X

THE CONQUEST OF THE AIR

Metal Planes, All Wings and Tail

In spite of all the advance that has been made in the last few years, airplanes to-day look very much as they did several years ago. They are not very different from the planes which the Wrights flew at Kitty Hawk more than a quarter of a century ago. True, the streamline effect, the cross-section of the wings, and all that, have been changed. These are improvements on the original model, not deviations from it.

Airplanes have crossed the Atlantic in both directions, they have stayed in the air for weeks at a time, they have attained speeds of over three hundred miles an hour, they have carried as many as 169 passengers at a single load, they have been powered with engines sufficiently strong to drive them straight up from the ground, and yet the fundamental principles of airplane design have not varied. They have merely been improved upon. The Belgian scientist, Maurice Boel, who has made an exhaustive study of the flights of birds, is of the opinion that his study can add nothing more than a few suggestions to the knowledge of airplane con-

struction. Nothing revolutionary has come out of his studies, they have merely pointed the way which minor changes must take. We have excelled the bird in almost every branch of flight. We still have something to gain in efficiency, but that is about all.

Perhaps the greatest change in the appearance of the planes has been brought about by the introduction of the all-metal plane. In the early days of flying an all-metal plane would have been considered a madman's dream; not only because of the weight, but also because of the corrosion, which in itself would be enough—it would have been thought at that time—to make such a project ridiculous. Those better acquainted with the behavior of metals would also have thought of crystallization and the resultant cracking due to the vibration. There were many reasons why metal could not be used and apparently none in its favor. But we have the all-metal plane, and it promises to be the plane of the future. This is because of the introduction of new corrosion-resisting, vibration-resisting, lighter-than-aluminum metals, the latest thing in alloys. The introduction of metal has greatly simplified design. It means less bracing.

Simplicity of appearance is also being accomplished by drawing the engines into the wings. This cuts down the wing resistance and adds greatly to the efficiency. Our largest multi-

motored planes are all being built in this fashion to-day. There is even a tendency to get rid of the fusilage entirely and to produce planes that are all wings and tail. At least one large passenger plane, now under construction, is being built in this way. The fusilage is wing-shaped and adds its share to the lifting power of the plane. The passengers will be, in reality, inside a wing.

Another change in design is the introduction of the so-called slotted wing. The slot is a safety device intended to give the plane greater stability, and it has proved of great value. The drawback to this device is that, as might be expected, it takes some of the control out of the hands of the pilot. The experienced pilot does not like this; he prefers to rely on his own ability to handle the plane. Thus the introduction of the slotted wing has been somewhat hampered.

Speeding Up the Take-Off

The major problem confronting the designers of airplanes to-day is that of reducing the space necessary for taking off and landing. For transport planes, heavily loaded, even our best airports to-day are none too large, and in the case of a forced landing it is next to impossible to find a space which will accommodate these machines. To reduce this space a quicker take-off and a lowered landing speed are needed.

The introduction of wheel brakes has helped

a great deal in both these directions. In the past designers have relied upon the tail-skid to bring their planes to a stop. This skid dragged on the ground at the take-off and prevented a rapid rise. The introduction of wheel brakes made it possible to hold the plane stationary until the engine was up to full speed. The brakes also made it possible to replace the skid with a wheel and so to cut down the space necessary for a take-off. This was obviously a great advantage.

Another step in the direction of quicker take-off and lower landing speeds has been the introduction of the so-called autogyroplane. This has a four-bladed fan of large dimensions mounted on a vertical shaft above the plane. The lift of the blades helps get the plane off the ground more quickly and enables it to come to rest at very slow speeds and consequently in a short distance. Such a plane remained stationary over Paris for a period of twenty minutes during tests. It is also true that the rotation of the windmill, as it is sometimes called, adds greatly to the stability of the plane. It is claimed that the stability is so great that it can be safely operated by a wholly inexperienced person.

Tests on the autogyro have shown that its efficiency is somewhat less than that of the average plane in use to-day. This has militated against its general acceptance. It is felt that the advan-

tages can be gained in other ways without the sacrifice of efficiency. One of the schemes which, according to the designers, is now in the experimental stage, is the use of auxiliary vertically-mounted engines which will drive the usual type of propeller during the landing and take-off. This, in effect, would be borrowing from the autogyro its scheme for take-off and landing, but dispensing for the present with the stabilizing effect during flight. This seems like a sensible procedure. It is generally known that little of the danger of flying occurs during the actual flight. Most of the accidents are on the take-off or on the landing, the latter period accounting for most of them.

In order to gain greater speed at the take-off—to shorten the distance needed before rising—the use of rockets is now being tried out. A battery of rockets would give a plane startling acceleration. A set of rockets held in reserve is also suggested for the purpose of clearing obstructions which might suddenly appear when flying through a fog. This idea, which has as yet hardly been tried (a single short flight with rockets has been made), promises to be the next step in the quest for a quick take-off.

Attempts are being made to lighten the landing gear. If this can be done it will become the practice on all planes to pull the landing gear up into the body of the plane during flight. This

would, in general, increase the speed on fast planes as much as fifty miles an hour. At the present time most landing gears are too heavy to be pulled up by any simple mechanical means. Shock absorbers are now regularly added to the landing gear for greater comfort on landing.

Airplane Engines

Wind resistance is being cut down in every possible way in the newer planes. One of the most recent innovations to contribute to this end has been the introduction of chemical cooling. A substance much more effective than water for engine-cooling has been developed, which will make it possible not only to reduce greatly the size of airplane radiators, but also to put the engine's cylinders in a straight line. At present, in the case of air-cooling, it is necessary to expose all the cylinders to the direct wind created by the plane in order to get sufficient cooling. It has not been found possible, by any other means, to get enough circulation around the cooling-fins of the cylinders. The same has been true of water-cooled engines. To put the cylinders in line would require a water-circulation over distances which have not been found practical. The new liquid will make cylinders in line possible. This will mean that we can stream-line the engine and so greatly cut down the head resistance here as well as in the reduced radiator size.

The introduction of the flying Diesel engine marks one of the most interesting and probably the most important advances in engine design in many years. Burning oil instead of gasoline adds to the safety of air travel immeasurably. Not only will it make fire almost a negligible factor while flying, but it will also eliminate the dangers of fire and explosion in the event of a crash. Crashes have snuffed out many lives that might have been saved but for the presence of gasoline. And because of the greater efficiency of the Diesel engine, the same supply of fuel in gallons will give twenty per cent. greater cruising range to the airplane. The ignition system is dispensed with in the Diesel, the ignition taking place in the cylinders, owing to the high temperature of compression. The compression is about eight times that of the gasoline engine This removes a source of possible engine failure and at the same time eliminates a source of interference with radio signals.

Engines are constantly being made with greater and greater power. Not many years ago 150 to 200 horse-power engines were the rule. To-day they run 400 to 500 horse-power, commonly. Engines of as much as 1,000 horse-power have been used in racing planes, and it is freely predicted that engines of 1,200 horse-power will soon be in use. Even with such large engines, because of the increasing size of the planes,

multimotored planes are becoming the rule. The increased safety of the multimotored plane is also a factor which is driving us to this method of propulsion.

One of the most interesting predictions that have recently been made is that in the near future we may expect to see gliders driven by outboard motors. The Bureau of Aeronautics of the United States Department of Commerce is responsible for this prediction. We now have gliders and we also have outboard motors. If someone should put the two together it would not be surprizing. As gliders sell for as low as a hundred dollars, and outboard motors for little more, this would give everyone a chance at aviation. In the past most of our planes have been designed primarily for military purposes. Our commercial planes have been copies of these. This has restricted the design and has also kept the planes much alike in size. Now that commercial aviation is becoming able to stand on its own feet, we may expect to see as much diversity of design here as we see in boats, for example, which range from the canoe up to lake steamers, freighters, and ocean liners. There will be planes for many and various purposes, each with its characteristic design.

In the matter of propulsion, much work is being done in the field of variable-pitch propellers. Changes in operating conditions are re-

flected in the efficiency of the airplane largely in the propeller pitch. If this can be varied to suit the changing conditions, it will add greatly to the operating efficiency. There is already much reason to believe that this problem has been solved by more than one individual.

Flying Blind

Flying has brought with it a host of new navigation instruments. All the old instruments, used for so many years on ships, have proved almost worthless for navigation of the air. Take the compass, for example. Because of the vibration of the plane, and often because of the lack of anything like an even keel, the magnetic compass is useless. This has led to the introduction of an entirely new instrument, the induction compass, which was made famous by the transatlantic flight of Colonel Lindbergh. This instrument depends, like the magnetic compass, on the earth's magnetic field. Coils of wire turning in the earth's field constitute a current generator. It is in fact a small dynamo using the earth's field as magnetic poles instead of having, as in the usual dynamo, poles built into it. The amount of current generated in this way is made to depend on the direction of the airplane by varying the position of the brushes which collect the current generated. When one has chosen his direction the brushes are set to give zero

current, and a variation to one side or the other of this direction will move the brushes so as to give either a positive or a negative value of current. Thus, once the direction has been chosen, one has only to keep the plane headed in such a way as to keep the needle of the instrument on zero to be sure that the direction he chose is being followed. Errors sometimes occur, however, owing to lack of uniformity in the earth's magnetic field.

To guide aviators on their course the radio beacon has recently come much into use. This may be of two types. In one a narrow beam of short-wave-length rays is focused and directed along the path to be followed. As long as the aviator is in this narrow beam he can hear the radio signals, but they are lost if he departs from it. In this way he is kept on the course. The other type uses two radio stations and the aviator is able to determine his position from the angle between these two beams as they reach him. Instruments now available do this for him automatically, so that he knows his course at all times. It requires no calculation on his part.

But knowing his location is not enough. The aviator also must know at times how high he is. This is often difficult or impossible to determine in night-flying or in fogs. For this reason altimeters have been devised. One of these operates by the interference of short radio waves. A wave

is sent to the ground, reflected, and combined with the original wave, which is still being sent out. The condition of interference between these two waves, original and reflected, is made evident by a change of intensity of the resultant audible signal. In this way the height above the earth is determined. This method operates best at high altitudes and is of little service in landing in the dark or fog. To meet this need an altimeter has been devised for low altitudes. It depends upon a differential capacity effect between a pair of metal plates on the fuselage and the earth. This device makes it possible to know the height accurately right up to within a few feet of landing. The radio beacon and the altimeter, together with other instruments necessary to flying, make it possible to fly blind. In tests it has been demonstrated that an experienced aviátor can take off, fly over considerable distance, return to the original airfield, and land successfully without the aid of sight. We can now fly wholly in the dark.

The aviator can receive weather reports while in flight. While he usually knows before taking off what weather to expect, the conditions sometimes change greatly, even in half an hour. In this event the aviator is warned by interrupting his signal beacon. He then, by remote control, tunes in his radio receiver and gets the message intended for him.

In the last few years tremendous strides have been made in the development of airfield floodlights and beacons. Lights of beam-candle-power ranging up into the millions are common. It is now generally agreed, however, that our main airways are lighted about as well as we can hope for in the present stage of lighting science. Recently much has been done with neon beacons in the hope of greater fog penetration with the red rays. For equal intensities of red and white light the red would be the more penetrating of the two. But white light can be produced in an arc which will contain as much red in addition to the other colors which go to make up white, as is contained in the ordinary neon lamp. Thus, until the neon lamp can be made much more powerful than it now is, it can offer little advantage in fog penetration.

Metal Ships Lighter than Air

The success of the German airship, the *Graf Zeppelin,* has again turned the attention of the world to this type of transportation. Something of the disrepute into which the airship had fallen has been wiped away, the numerous accidents have been forgotten, and once more we are asking, "What is the future of the lighter-than-air flying machine?"

It is true that the lighter-than-air machine is a practical device in one sense of the word. The

Graf Zeppelin has demonstrated this in its round-the-world flight. And yet not very much improvement has been made in this machine as compared to its predecessors. Perhaps the only notable change has been in the fuel. This ship has adopted blau gas for fuel—a petroleum product which has a density about equal to that of air. Thus, as the gas is used up, the weight of the ship and contents does not vary. This makes it unnecessary to valve off the lifting gas as the fuel is used, as is necessary with heavier-than-air fuel, unless some other provision is made to overcome the decreased weight. In the United States dirigible, the *Los Angeles,* the same purpose is accomplished by condensing the water vapor from the engine exhaust. This compensates for loss of weight due to the use of gas. Where blau gas is not available the *Graf Zeppelin* has successfully used other gases or combinations of gases for its engines.

One of the dangers of the lighter-than-air ship has been in the lifting gas. This has almost invariably been hydrogen, which is very explosive when mixed with air. Only in the United States is there a supply of another and safer gas, helium, which can be successfully used as a substitute. As it does not appear likely that helium will ever be found anywhere in great quantities, the dirigibles may have to depend on hydrogen gas if many of them are built, in which case they

would always be faced with the danger of explosion.

Another great drawback in the case of the dirigible is its slow speed. This varies from 50 to 100 miles an hour. Normally one takes to the air to gain time, and it is obvious that, at least in overland flight, nothing could be gained over our usual train service. Over long water distances there is some advantage in time, as has been demonstrated by the *Graf Zeppelin.* This ship was built apparently with the thought that this was the only commercial possibility open to such a craft. It still does not appear to be feasible to establish a regular schedule, however.

Perhaps the most interesting development in lighter-than-air machines, from the purely scientific viewpoint, is the all-metal dirigible. It has been possible to build a ship of all metal that is but slightly heavier than the fabric ships. The metal is called alclad. It is an aluminum alloy which, in practise, is coated with a thin layer of aluminum. The aluminum coating resists corrosion better than the alloy. The new United States Navy ship, the *ZMC-2,* is built of alclad fabricated in sheets 0.0095 of an inch in thickness—about three times as thick as a sheet of newspaper.

The use of this metal makes for simplification of construction. It will stand considerable longitudinal stress and consequently many braces and

tie-wires can be eliminated from the usual design. The main frame consists of simple hoops of an aluminum alloy, which are lightened by a cellular construction.

In the past the great advantage of the dirigible has been in the number of passengers it could carry. But now its passenger-carrying record has been equaled by the airplane. It is difficult to see, then, just what the future has in store for the Zeppelin type of airship; but it will doubtless make a place for itself. Man has the satisfaction, at least, of knowing that he can build such machines, that he can conquer the air in more ways than one.

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